URINE, URINARY DEPOSITS,

AND

CALCULI,

AND ON THE TREATMENT OF URINARY DISEASES.

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WITH NUMEROUS ILLUSTRATIONS, AND TABLES FOR THE CLINICAL EXAMINATION OF URINE.

BY

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SECOND EDITION.

LONDON:
JOHN CHURCHILL & SONS, NEW BURLINGTON STREET.

MDCCCLXIV.

WESTMINSTER:
PRINTED BY W. BLANCHARD AND SONS,
62, MILLBANK STREET.

DEDICATED TO THOSE WHO

WORKED WITH THE AUTHOR IN HIS LABORATORY,

AND AT A VERY EARLY PERIOD OF HIS CAREER

GAVE HIM THE

WARMEST ENCOURAGEMENT AND SUPPORT.

1852.

PREFACE

TO

THE SECOND EDITION.

THE Author has endeavoured to increase the usefulness of the Work by the addition of observations on the treatment of urinary diseases. Experience has taught him that the treatment of many chronic and obstinate diseases of this class is more successfully carried out by attention to the general physiological changes going on in the system, and by the use of *simple* remedies in suitable doses, given regularly, and persevered with for a considerable time, than by the employment and frequent change of complex formulæ. In common with many physicians, the Author feels that the treatment of disease may now be conducted upon well recognised and intelligible principles, and that the system of ordering a number of different substances should be deprecated, because evidence has proved it to be useless to the patient, whilst it must foster mystery in connexion with our art, and greatly retard the advance of medicine. The reader will, therefore, not find a list of all the drugs that have been advocated as having a special influence on the urinary organs; nor will he meet with complex recipes containing several different ingredients, the action of which is very imperfectly understood.

The general arrangement of the urinary deposits adopted in the first edition has been retained, as increased experience in teaching has convinced the author of its real practical utility. If the reader will refer to the arrangement of the contents in page xi., he will readily find any subject he requires. In addition, however, a copious index has been made. New observations and several new figures have been introduced, and a considerable part of the work has been entirely re-written, while new matter, to the extent of nearly 100 pages, has been added.

For the sake of convenience, and for cheapness, the work has been published in the form of a Hand-book, but it contains much original matter, and the results of greater labour than the reader would be led to suppose from a superficial review of the contents.

61, Grosvenor Street, W.,
October 1st, 1863.

PREFACE

TO

THE FIRST EDITION.

The Lectures which are now published were first given in November, 1852, at a laboratory adjoining King's College Hospital (27, Carey Street, Lincoln's Inn Fields), which I had arranged for the study of those branches of chemistry and microscopical inquiry which have a special bearing on medicine. Several courses of lectures and demonstrations were given during the seven succeeding years; but of late, increased work in other departments has prevented me from devoting so much of my time to this branch of teaching.

The course on urine included oral lectures and practical demonstrations, in which every pupil performed the experiments with his own hands, according to the directions given in the Tables, which will be found at page 411 of the present work.

The lectures were first published in the *British Medical Journal*, and are now printed in a collected form, with several additions. I have endeavoured to restrict myself, as far as possible, to those parts of the subject which are of practical importance in investigating the nature of a case. It must be borne in mind that the Lectures were given to practitioners, most of whom had far larger experience in practice than myself. Little advantage, therefore, could have resulted under these circumstances from discussing special questions connected with the treatment of disease, and almost the whole time was devoted to the practical examination of

the urine and urinary deposits by the microscope, and by applying the appropriate tests. I have thought it right to retain this character in the present work, and only a few very general remarks will be found with reference to the treatment of urinary diseases.

I have had frequent occasion to refer to numerous works, and have inserted many references in the text between brackets. The names of almost all the authors consulted will also be found in the index.

Nearly all the analyses have been made by myself, and the drawings have in most cases been copied by me on the blocks, which were afterwards engraved. Those illustrating the chapter on the kidney have been very recently copied from specimens carefully prepared. Only comparatively few illustrations of the salts of the urine and of urinary deposits will be found in this work, as they have been already published in the "*Illustrations*," to which frequent references will be found. I have endeavoured, as far as possible, to give accurate copies of the objects; and almost all the drawings have been traced directly on the wood-blocks or lithographic stones. Each object has been represented of the exact size it appeared. The magnifying power is given, and a scale appended, by which anyone can measure each object.

References to different parts of the work are inserted where required, especially in the Tables at the end of the volume. Pains have been taken to arrange the subjects to be discussed in the most convenient manner. A glance at the arrangement which immediately follows will at once give the reader an idea of the contents of the book, and the order in which the subjects are treated of.

LIONEL S. BEALE.

61, GROSVENOR STREET, W.,
March, 1861.

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ORIGINAL ANALYSES OF URINE.

CHAPTER I.

TESTS.—CHEMICAL APPARATUS AND INSTRUMENTS NECESSARY FOR THE CLINICAL EXAMINATION OF URINE. *Balance—Weights, Test-tubes—Test-tube Holder—Small Retort Stand—Tripods and Wire Triangles—Spirit-lamp—Platinum Capsules—Water-bath—Beakers—Conical Glasses—Evaporating-basins—Wash-bottle—Glass Funnels—Filtering-paper—Glass Measures—Stirring-rods—Test-papers—Thermometer—Blowpipe—Pipettes—Urinometers and Specific Gravity Bottles—Clinical Pocket Microscope—Object Glasses—Microscope Lamp—Glass Slides—Thin Glass—Watch Glasses—Glass Cells—Brass Forceps—Stage Micrometer—Neutral-tint Glass Reflector—Bottles, with capillary orifices.*

FOR the general clinical investigation of urine, the practitioner requires certain tests and apparatus for performing chemical analysis, and instruments for examining urinary deposits by the microscope. I purpose, in the present chapter, to refer briefly to those instruments and pieces of apparatus I have found most necessary, inexpensive, and useful. These can be readily obtained of most instrument makers.

TESTS AND CHEMICAL APPARATUS.

1. Tests.—The principal reagents required for qualitative and quantitative analysis of the urine are enumerated below. They should be kept in stoppered bottles, of from two to four ounces' capacity. The strength of the solution required varies somewhat in different test solutions; but from ten to fifty grains of the salts may be dissolved in each ounce of distilled water. Distilled water

should be kept in a quart bottle; and it will be convenient to keep one of the wash-bottles represented in Fig. 10, Plate II., also filled with distilled water.

		Strength.
Alcohol	HO,C^4H^5O	Sp. gr. 0·83
Sulphuric Acid	HO,SO^3	Sp. gr. 1·84
Hydrochloric Acid	HCl	Sp. gr. 1·20
Nitric Acid	HO,NO^5	Sp. gr. 1·20
Oxalic Acid	C^2O^3,HO	50 grs. to 1 oz.
Acetic Acid	HO,C^4H^3,O^3	Pharmacopœia.
Ammonia	NH^3	Sp. gr. 0·88
Oxalate of Ammonia	NH^4O,C^2O^3+Aq	80 grs. to 1 oz.
Potash	KO	Sp. gr. 1·060
Ferrocyanide of Potassium	$K^2,FeCy^3+3Aq$	25 grs. to 1 oz.
Chloride of Ammonium	NH^4Cl	50 grs. to 1 oz.
Lime Water	CaO,HO	Sat. sol.
Carbonate of Soda	NaO,CO^2+10Aq	160 grs. to 1 oz.
Phosphate of Soda	$2NaO,HO,PO^5+24Aq.$	50 grs. to 1 oz.
Chloride of Calcium	$CaCl$	50 grs. to 1 oz.
Chloride of Barium	$BaCl$	50 grs. to 1 oz.
Perchloride of Iron	Fe^2Cl^3	100 grs. to 1 oz.
Sulphate of Copper	CuO,SO^3+Aq	50 grs. to 1 oz.
Nitrate of Silver	AgO,NO^5	25 grs. to 1 oz.
Bichloride of Mercury	$HgCl^2$	25 grs. to 1 oz.
Bichloride of Platinum	$PtCl^2$	Sold in solution.

Fehling's Solution.—For mode of preparation, *see* § 47.

2. **Balance.**—A very efficient balance, which weighs to the 1-50th of a grain, and bears 1,000 grains in each scale, and is adapted for the quantitative examination of urine and other animal fluids and solids, may be obtained of Mr. Becker, of the firm of Elliott Brothers, Strand, for the sum of £3.

3. **Weights.**—It is desirable to be provided with *gramme*, and also with *grain* weights. These are furnished with the scales.

4. **Test-tubes**, of various sizes, will be required. The observer should also be furnished with the rack and drainer represented in Plate I., Fig. 1.

Fig. 1.

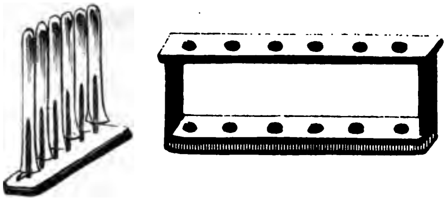

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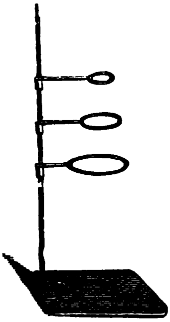
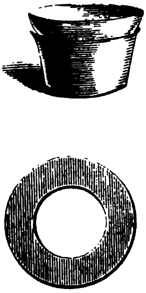
Fig. 2.



§ 6.

Fig. 3.



§ 10.

Fig. 4.

§ 5.

Fig. 5.

7

Fig. 6.

a

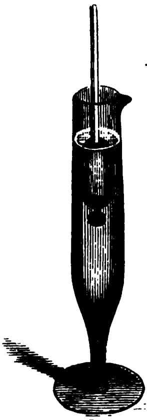
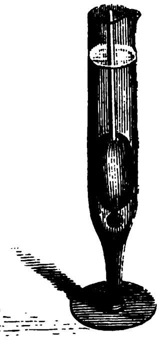


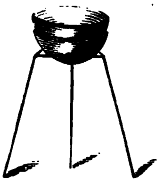
Fig. 7.

b



§§ 12, 23.

Fig. 8.



§ 7.

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5. Test-tube Holder.—A very simple form is represented in Plate II., Fig. 11.

6. Small Retort Stand, as seen in Plate I., Fig. 2; or attached to the spirit-lamp, as in Fig. 4.

7. Tripods and Wire Triangles, for supporting platinum capsules or foil, while the organic matter is being burned off. Plate I., Figs. 5, 8.

8. Spirit-lamp. — The ordinary glass spirit-lamp is the most convenient form.

9. Small Platinum Capsule and Platinum Foil. — A capsule about two inches in diameter will be large enough. This can be purchased for 12*s.* or 14*s.* It should be exposed to the clear smokeless flame of a spirit-lamp, or to that obtained by burning coal gas mixed with air, as it issues through fine wire gauze, or from a small conical tube placed over the gas-burner. Care must be taken that no lead or pewter comes into contact with the platinum when heated, or it will be instantly destroyed.

10. Water-bath. — A very simple form of water-bath is represented in Plate I., Fig. 3; or a small saucepan may be used. But when the observer desires to make many careful analyses of urine, he should be provided with a larger water-bath, so that four or five basins may be placed over it at one time. Several rings, of various sizes, cut out of thin sheet copper, will be required to support basins of different sizes over the water-bath. A little hot-water drying-oven is necessary for careful quantitative determinations. The injecting-can ("*The Microscope in Medicine,*" page 25, fig. 59) may also be used as a water-bath.

The porcelain basins with residues, which have been dried over the water-bath, should be allowed to cool before being weighed. The observer will find it useful to have two or three glass shades, about 9 inches in diameter, with shallow glass dishes, for containing strong sulphuric acid, about four or five inches in diameter. Upon the glass dish, about half filled with the sulphuric acid, is placed a piece of wire gauze, or perforated zinc, to support the basins. In this manner the residues may be allowed to cool, without absorbing water, and they may be kept dry for some time, if requisite.

11. Two or Three Nests of Beakers.*

12. Conical Glasses, of the form represented in Plate I., Figs. 6, 7, or in Plate II., Fig. 9. The former combines the glass for the urinometer with a conical glass for collecting urinary deposits. This is a most useful form of conical glass. It was devised by Dr. Budd.

13. Porcelain Evaporating-basins, of various sizes, from eight ounces to half an ounce capacity.

14. Wash-bottle, for washing precipitates on filters (Plate II., Fig. 10).

15. Glass Funnels, of various sizes (Plate III., Fig. 13).

16. Filtering-paper, which can be purchased of the instrument makers, or of most stationers, under the name of white blotting-paper. The mode of folding filtering-papers is represented in Plate II., Fig. 12, or they may be purchased, ready cut in circles, of the operative chemists.

17. Glass Measures.—One pint measure, one 4-ounce, one 1-ounce, 1,000-grain measure, cubic inch measure. The cubic centimeter measures are described in Chapter II., on "*The Volumetric Analysis of Urine.*"

18. Stirring-rods.—These are made of ordinary glass rod, rounded at each end in the blowpipe flame; or of pieces of glass tube, the ends of which are drawn off and closed in the flame of the spirit-lamp or blowpipe.

19. Test-papers.—Blue litmus and reddened litmus.

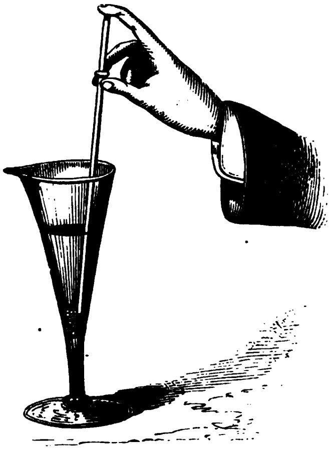
20. Thermometer.

21. Blowpipe.—An ordinary gas-fitter's blowpipe, which costs 6*d.*, answers every purpose.

22. Pipettes, of two or three sizes (Plate III., Fig. 14*a*, *b*).

* Glass and porcelain apparatus may be obtained of Messrs. Powell, of the Whitefriars Glass Works, or they will be furnished by the instrument makers.

Fig. 9.

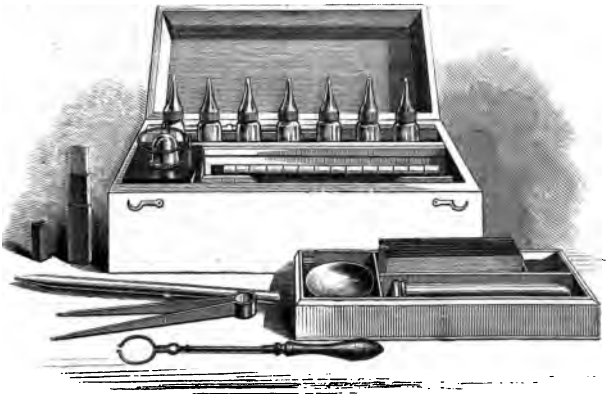


§ 12.

Fig. 10.

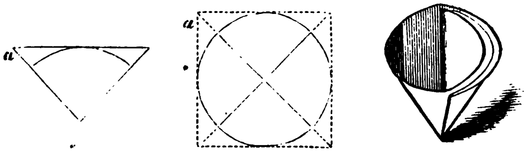
§ 14

Fig. 11.



§§ 5, 34.

Fig. 12.



§ 16.

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23. Urinometers—Specific Gravity Bottles, for taking the specific gravity of urine. The specific gravity of a fluid is obtained most correctly by ascertaining the weight of equal bulks of the fluid to be examined, and distilled water. For this purpose, a small bottle, with a tubular stopper, holding exactly 1,000 or 500 grains of distilled water, at a temperature of 60°, is the most convenient form of apparatus (Plate III., Fig. 16). All that is necessary is to fill the bottle carefully with the urine, wipe it dry, and then weigh it, after having counterpoised the bottle. The number of grains which the fluid weighs is the specific gravity in the case of the 1,000-grain bottle, double the weight for the 500-grain bottle, four times the weight for a bottle holding 250 grains, and so on, in like proportion.

This method, although perfectly exact, and readily performed where a good balance is at hand, is nevertheless too tedious and troublesome for the practitioner in a general way, and, in the sick-wards, a much simpler, though less correct method, is usually resorted to. The specific gravity is obtained by a small hydrometer, usually termed a *urinometer*. The form of this instrument, and the mode of using it, are well known; but there are one or two points in its construction and management which it may be well for me to refer to. As sold, these instruments are often nearly useless, in consequence of the carelessness displayed in their manufacture. Out of twenty instruments, I have found several differing as much as ten degrees from each other. If the stem of many urinometers be examined, it will be found that all the degrees marked upon it are equal, which clearly ought not to be the case (Plate III., Fig. 15*a*); for when fluids of low specific gravity are operated on, a very small portion of the stem remains above the surface of the liquid (Plate I., Fig. 6*b*), while the reverse holds with respect to liquids of great density. In the latter case, there is, of course, a much greater weight of stem above the liquid, tending to force the instrument lower in the fluid than in the former (Plate I., Fig. 6*a*). Allowance must also be made for the fact that the fluid becomes denser as we pass from the upper to the lower strata.* The tendency of the instrument to indicate a higher density than the real one, renders it necessary that the degrees should *decrease* in length from the upper towards the lower part of the stem. The practitioner should carefully examine

* This error has been corrected by Mr. Ackland, of Messrs. Horne and Thornthwaite's, where accurately graduated instruments may be obtained.

his urinometer, to see that there is this difference in the degrees (Plate III., Fig. 15*b*), and if not, it should be changed. I strongly recommend everyone to test the urinometer by immersing it in fluids, the specific gravity of which has been ascertained by the bottle, or by a well made and previously corrected urinometer. If the degrees are incorrect, the observer can always bear in mind the amount of error, and allow for it in taking the specific gravity of different specimens of urine. The vessel which is employed for receiving the urinometer should not be too narrow, in case the bulb should rub against the sides, when it becomes difficult to ascertain the real density. Its diameter should be rather more than a quarter of an inch over that of the widest part of the bulb of the urinometer. The glass delineated in Plate I., Fig. 6, is a very convenient form.

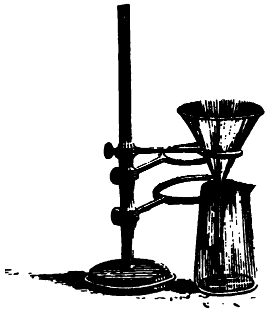
Another method of taking the specific gravity, which is sometimes followed, consists in having a number of small glass bulbs, with the density of the fluids in which they neither sink nor swim marked upon them. By placing one after another in the urine, one is found which remains just beneath the surface, and the number upon it indicates the specific gravity of the fluid.

⁂ The chemical apparatus required for the analysis of urine will be provided by Messrs. Bullock & Reynolds, 3, Hanover Street, W.; Messrs. Griffin, Bunhill Row, E.C.; and other Operative Chemists; or they will be procured for the practitioner by most of the Instrument Makers.

Apparatus required for the Microscopical Examination of Urinary Deposits.

24. Clinical Pocket Microscope.—This is a very simple and inexpensive instrument, which I have lately arranged for the microscopic examination of urinary deposits and other substances. It may be used as a field microscope, and will be found a most useful form of instrument for the practitioner. When closed, it is only six inches in length, but when arranged for examination, the tube is drawn out as long as that in the ordinary microscope. Any powers can be adapted to it; and direct light, or light reflected from a mirror, may be employed. I have now used this instrument for some time for teaching in the wards, and find that it answers its purpose well. It may be fitted up with mirror, pipettes, slides and cells, in a leathern case. The instrument is made by Mr. Highley, 70, Dean Street;

Fig. 13

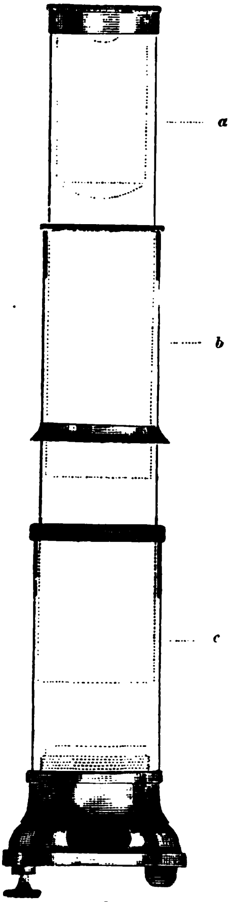


§ 15.

Fig. 14.

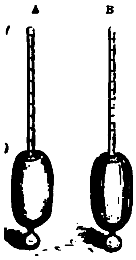
§ 22.

Fig. 17.



§ 24.

Fig. 15.

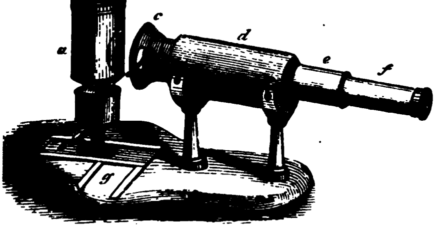


§ 23.

Fig. 16.

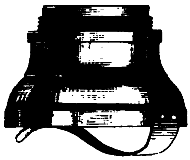
§ 23.

Fig. 18.



§ 24

Fig. 19.



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Messrs. Powell & Lealand, 170, Euston Road; Mr. Salmon, 100, Fenchurch Street; and by Mr. Matthews, Portugal Street, Lincoln's Inn. The clinical microscope is represented in Plate III., Fig. 17. It costs, with the eye-piece, but without object glasses, 25*s*. The arrangement of the spring, by which the preparation is kept in contact with the stage, while every part of the field is examined, is represented in Fig. 19. I have had this instrument fitted to a small stand, with a lamp for use by night, and a mirror for day, so that it can be very easily handed round in a lecture-room. I find this arrangement most convenient for demonstrating objects to large classes. The stand, with the clinical microscope, is represented in Plate III., Fig. 18. It is convenient also to be provided with a simple student's microscope, with large stage. (*See* the "*Microscope in Medicine.*") The tube of an ordinary microscope can easily be made moveable and fitted with the end tube and stage of the clinical microscope—a plan which has been carried out by Mr. Highley.

25. Object-glasses required.—The *quarter of an inch*, magnifying about 200 diameters, and *the inch*, magnifying from 30 to 50 diameters, are the two most useful object-glasses for the purposes of the medical practitioner. The best English objective costs about £5, but good powers may be obtained for about 30*s*.

26. Microscope Lamp.—An ordinary French lamp affords a very excellent artificial light, especially if provided with a blue glass chimney. The best form of gas lamp has been arranged by Mr. Highley, of 70, Dean Street, Soho Square. This lamp is figured in Plate IV., Fig. 20.

27. Glass Slides—the only slides used—should be three inches long by one inch broad. They may be purchased, at from 2*s*. to 6*s*. per gross, of Messrs. Claudet and Houghton, 89, High Holborn, E.C., and of most instrument makers.

28. Thin Glass, cut into squares and circles. This may be obtained of the various instrument makers, and of Messrs. Claudet and Houghton.

29. Watch Glasses, of various sizes. Watch glasses are very convenient for evaporating small quantities of fluids. The common glasses are those which are required. They cost 1*s*. per dozen.

30. Glass Cells, for examining urinary deposits. A simple form of cell is represented in Plate V., Fig. 25, but I have found the so-called "animalcule cages" most convenient instruments for the examination of urinary deposits. The best form is represented in Plate V., Fig. 24, which is supplied by Messrs. Powell and Lealand. Fig. 26 is a section of a smaller one, which can be used with the clinical microscope.

31. Brass Forceps, supplied by the microscope makers.

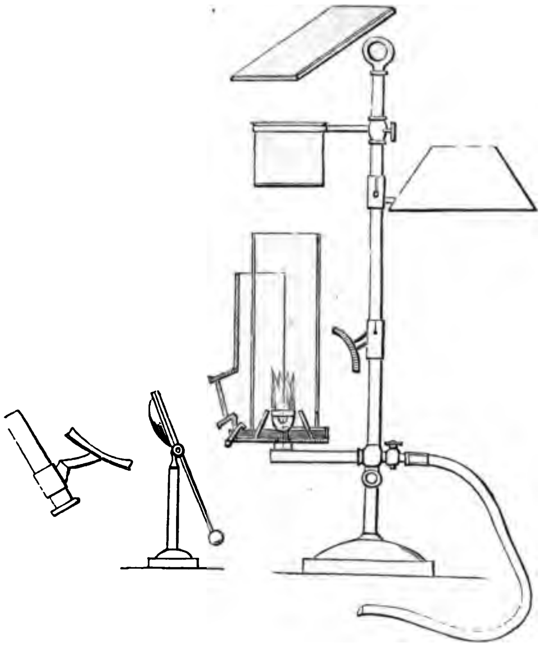
32. Stage Micrometer, divided into 100ths and 1,000ths of an inch. This is required for measuring objects, according to the plan described in "*The Microscope in Medicine*," pp. 41—45. A scale, divided to 1,000ths of an inch, and magnified 215 diameters, is represented in Plate V., Fig. 23.

33. Neutral-tint Glass Reflector, for tracing the outline of objects (Plate V., Fig. 22). It is very important that the observer should be familiar with the methods of drawing and measuring objects accurately. The arrangement of the microscope for tracing the outline of objects, with the aid of the neutral-tint glass reflector, is represented in Plate IV., Fig. 21; see also, "*The Microscope in Medicine*," p. 33.

34. Bottles with Capillary Orifices.—These bottles are most convenient for testing minute quantities. Different forms are represented in Plate V., Figs. 28, 30. They may be obtained separately, in boxes containing 6 or 12 (Fig. 27); or fitted up in a box, with other apparatus required for testing urinary deposits and calculi (Plate II., Fig. 11).

These bottles are filled as follows:—A little distilled water is poured into a small porcelain basin, the tube being inverted so that the orifice dips beneath the surface of the water. Heat being now applied to the bottle, by means of a spirit-lamp, the air in the interior is expanded, and partially expelled. As the bottle becomes cool, a certain quantity of the fluid rises up into its interior. A few drops having been introduced in this manner, the bottle is held in the test-tube holder over the spirit-lamp; and, when the water boils, and the greater part has been converted into steam, the orifice is quickly plunged a short distance beneath the surface of the liquid

Fig. 20.



§ 26.

Fig. 21.

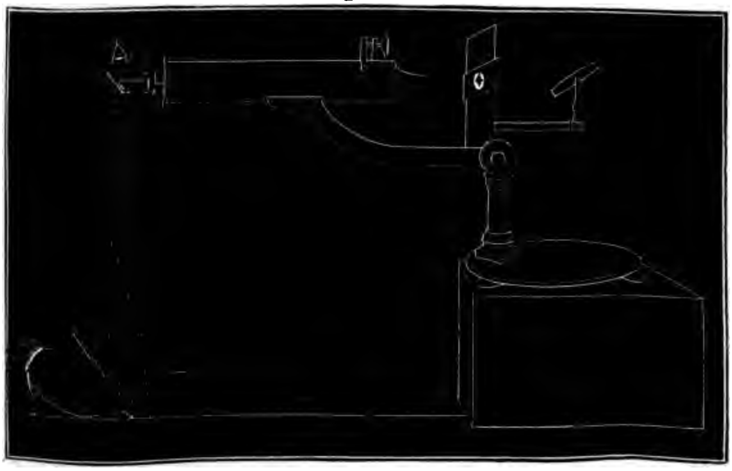


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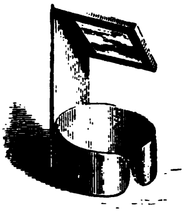
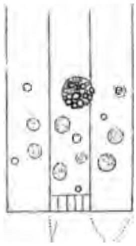
Fig. 22.



§ 33.

Fig. 23.



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§ 32.

Fig. 24.

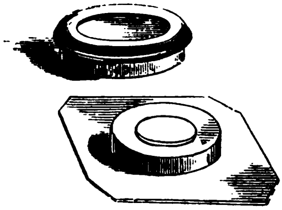

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Fig. 25.

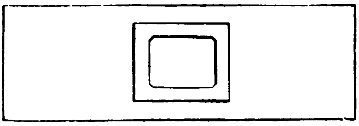

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Fig. 26.

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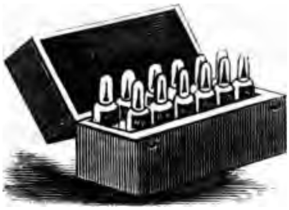
Fig. 27.



§ 34.

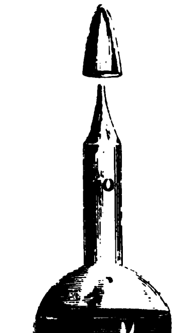
Fig. 28.

§ 34.

Fig. 29.

§ 34.

Fig. 30.



§ 34.

To follow **Plate IV.**

to be introduced, which has been already placed in another small porcelain capsule. As the steam condenses, the solution will, of course, rise up, and would completely fill the little bottle, if it were maintained in this position, but, when about three parts full, it is to be removed. If completely filled, it would be difficult to expel a drop, when required. A certain quantity of air, therefore, is allowed to remain within the bottle; this being expanded by the warmth of the hand, the quantity of fluid required is forced out. For microscopical purposes, these little bottles possess many advantages over the ordinary stoppered bottles. In the first place, a most minute quantity of the test can be obtained, and this can be carefully regulated. Secondly, there is no danger of the reagent being spoilt by the introduction of various foreign substances from without. If an ordinary stoppered bottle be used, a drop of fluid is generally removed with a pipette, or stirring-rod; but if these should not be quite clean, foreign substances may be introduced, and the reagent spoilt for further operations. Carelessness upon this head will lead to the greatest inconvenience, and may be productive of the most serious mistakes. Thirdly, testing by means of these little bottles can be conducted in a very short space of time; and all the tests required, even for a very complete qualitative examination, can be packed in a very small compass.

A useful form of pipette, which can be adapted to ordinary bottles, in the form of a stopper, is represented in Plate V., Fig. 34. The tube is very narrow near the end (*c*), so that a very small drop can be obtained. A piece of India-rubber is stretched over the other extremity, and by slightly pressing this a drop is expelled. This plan is recommended by Dr. Lawrence Smith, of Louisiana.

All the necessary apparatus required for the ordinary qualitative examination of urine, with tests, in bottles with capillary orifices, and apparatus necessary for the microscopical examination of urine, have been arranged in a little case, as represented in Plate II., Fig. 11. This can be purchased of Mr. Highley.

⁂ The microscopical apparatus required for the examination of urinary deposits may be obtained of Mr. Baker, Holborn; Mr. Highley, 70, Dean Street, W.; Mr. Matthews, Portugal Street, Lincoln's Inn; or it will be procured for the practitioner by the instrument makers.

CHAPTER II.

THE VOLUMETRIC PROCESS OF ANALYSIS FOR ESTIMATING SOME OF THE CONSTITUENTS OF URINE. APPARATUS REQUIRED. *Burettes—Pipettes—Cylindrical Glass Measure—Beakers and other Apparatus—Weights and Measures—On the Estimation of Urea and Chlorides; Determination of the Urea; Preparation of the Solution; Performance of the Analysis—Determination of the Chloride of Sodium; Preparation of the Solution; Performance of the Analysis—Estimation of Phosphoric Acid; Preparation of the Solution; Performance of the Analysis—Determination of the Sulphuric Acid; Preparation of the Solution; Performance of the Analysis—Determination of the Sugar; Performance of the Analysis—Dr. Davy's Method of Determining Urea.*

ALTHOUGH the general processes adopted for the estimation of the various constituents might be systematically arranged under their respective heads, it has been thought more convenient to treat of the subject of volumetric analysis in one chapter.

The ordinary methods for determining the proportion of the most important constituents in the urine possess many defects. Chemists have long found that the results are inaccurate, and not to be depended upon at all, unless great care has been taken in the process of analysis; while, at the same time, they are very laborious, and require an amount of chemical skill which few possess, unless they have been in the habit of working for some time in a laboratory. Practitioners have for years past recognised the importance, in many cases, of being acquainted with the amount of the urinary constituents removed from the body in twenty-four hours, and have desired to know how these proportions are affected by certain physiological conditions of the system, or by the administration of

remedies, or by disease. Till within the last few years, the greatest practical difficulties existed with reference to carrying out such researches. The physician was not chemist enough to undertake them; and the pure chemist, not having sufficient knowledge of medicine to enable him to see the use of such inquiries, was not interested in the matter. In practice, it will, I think, be found that all such investigations, if they are to be of any real use, must be carried on by a physician who at the same time is acquainted with chemistry. Within the last few years, the process of volumetric analysis has been introduced, principally by Professor Liebig, to whom we are entirely indebted for the excellent and accurate plan of estimating the urea and chloride of sodium. Physicians may now, with very little practice, carry on these researches; and when a sufficient number of observations have been made in various cases of disease, very important facts will, no doubt, be elicited. These processes are not free from error; but they are sufficiently accurate for all the requirements of the physician who desires to know the relative variation of the principal substances in different cases, rather than to determine the exact quantity present in a given specimen of urine. The volumetric process is, at least, as accurate as the old plans; and if it be carefully carried out, with attention to certain points of detail, much more so. In cases in which very accurate results are required, I must refer the reader to Neubauer and Vogel's treatise on the urine, where rules for all the corrections are given; but, for all ordinary purposes, the plan recommended below has been found in practice sufficiently exact. The directions here given were obtained after performing the different processes several times, and were arranged by my friend and former assistant, Dr. Von Bose, whose original paper on the subject was published in the "*Archives of Medicine*," Vol. I.

The principle of volumetric analysis is based upon the fact, that substances combine in definite and equivalent proportions. If, therefore, we accurately measure the proportion of the test required to combine with the whole of the substance present in a solution, a simple calculation, according to the chemical equivalents of the two bodies, will enable us to obtain the desired result. For instance, suppose the quantity of sulphuric acid (SO^3) in a solution is to be determined. We know that to precipitate 40 parts of sulphuric acid, exactly 122 parts of crystallised chloride of barium ($Ba\,Cl + 2\,HO$) are required,—or for 1

part of sulphuric acid, 3·05 parts of chloride of barium,—or for ·01 gramme = ·154 grain of sulphuric acid, ·0305 gr. = ·747 gr. of chloride of barium. Now, if we dissolve 30·5 gr. = 471·04 grs. of chloride of barium, in 1,000 cubic centimeters of water = 15,444 grs., or about 1¾ pint, every cub. cent. contains ·0305 gr. = ·47 grs. of chloride of barium; and if we place this solution in a tube, graduated to *cubic centimeters* or *grains*, and allow it to flow gradually into a solution of sulphuric acid as long as we get a precipitate, the number of cub. cents. used indicates the quantity of *chloride of barium* employed; and from these data we at once ascertain the proportion of *sulphuric acid* contained in the solution.

Apparatus required for Volumetric Analysis.

35. Burettes or Graduated Tubes (Plate VI., Fig. 31*d*).—It is convenient to be provided with one or more holding 50 cub. cents., and graduated to half cub. cents. The lower part of the tube is drawn to a small calibre; and to its extremity a small piece of glass tube, about two inches long, is connected by a piece of India-rubber tube, *f*, so arranged that it can be compressed at pleasure by a wire-spring, just below *f*, as represented in the figure. When the two extremities of this spring are pressed by the finger and thumb, fluid will flow down the tube; and when the pressure is removed, the tube is rendered impervious. This little apparatus serves the part of a stop-cock, and possesses many advantages over the latter. Care must be taken to keep the tube perfectly clean, and the India-rubber should be well washed after every analysis. The apparatus required for the volumetric method of analysis is represented in Plate VI., Figs. 31, 32. *a*, is a glass jar, capable of holding 500 C.C., graduated to 5 C.C. *b*, a pipette, graduated to hold 20 C.C. *c*, a piece of India-rubber tube for the convenience of allowing the fluid to escape very slowly when pressure is applied by the finger and thumb. *d*, is the burette, which is capable of holding 50 C.C., and graduated to half C.C. The numbers are not marked on the tubes in the figure. *e*, *e*, are small pieces of wide India-rubber tube to hold the burette in its place. *f*, a small piece of India-rubber tube connecting the extremity of the burette with the spout, and capable of being compressed by the spring, the form of which is represented at *g*. The mode of using the apparatus is also seen in this figure.

Fig. 31.

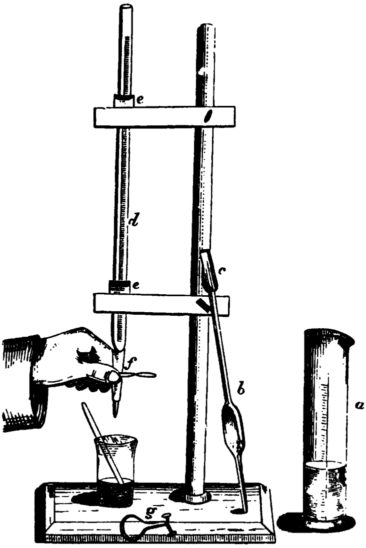


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Fig. 32.

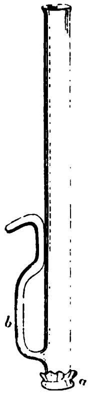

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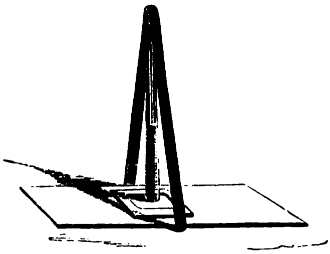
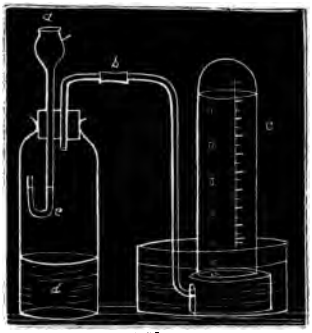
Fig. 33.



§ 55.

Fig. 34.



§ 50.

Fig. 35.

§ 58

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The pipette is figured at *b*, Fig. 31. It is convenient to be furnished with one of 20 C.C.=308·88 grs. capacity, one of 15 C.C. =231·66 grs., and one of 10 C.C.=154·44 grs. The *Cylindrical Glass Measure*, graduated to 500 C.C., is represented at *a*.

The little apparatus represented in Plate VI., Fig. 32, was constructed by me, for the purpose of filtering a little of the fluid from the deposit, in order to see if all the substance was precipitated. Filtering-paper is tied round the lower extremity, *a*. By plunging this beneath the fluid, the solution rises quite clear in the interior, and may be poured through the spout, *b*, into a small test-tube kept for the purpose. The drawing represents the tube half the real size. In estimating the quantity of sugar, this little apparatus will be found very convenient.

Beakers, stirring-rods, test-paper, funnels, and porcelain basins, with a tripod or small retort-stand, with a spirit-lamp or gas-lamp and small sand-bath, are also required.*

The test-solution is poured into the burette at the top till it is nearly full. A beaker is then placed beneath the orifice, and a certain quantity of fluid allowed to flow from the tube until the upper surface reaches zero on the scale. The line on the burette should always correspond to the lowest part of the thick line at the top of the fluid, caused by the capillary attraction of the walls of the tube. Care must be taken that the part of the tube below the India-rubber joint is also quite full of fluid.

It is desirable that the pipettes should be provided at their upper extremity with a short piece of India-rubber tube, *c*, Fig. 31, as, by properly-applied pressure upon this with the finger and thumb the fluid may be allowed to escape very gradually.

36. Weights and Measures.—In these directions, *weights* are expressed in grammes and grains, and *measures* in cubic centimeters and grains, so that the observer may adopt either as a standard of comparison. Tubes graduated to grains can easily be obtained, if required. The grammes, gr., and cubic centimeters, C.C., being always placed before the grains, grs. Thus, ·01 gr.=·154 grs. is to be dissolved in 10 C.C.=154 grs. of water.

* The apparatus referred to may be obtained of Messrs. Bullock and Reynolds, Hanover Street, Hanover Square, who also supply the test-solutions ready graduated; and of Messrs. Griffin, Bunhill Row, E.C.

37. Estimation of Urea and Chlorides.—The determination of urea and chlorides is effected by solutions of penitrate of mercury ($HgO.NO^5$). The principle upon which the method depends is this, that *chlorine* gives a soluble, and *urea* an insoluble, compound with peroxide of mercury (HgO), while chlorine has a greater affinity for mercury than urea has; therefore, if pernitrate of mercury ($Hg.O.NO^5$) be added to a solution containing chlorine and urea, the chlorine will first combine with the mercury, and no precipitate of urea and mercury will take place until all the chlorine has been saturated; and if we observe how much of the solution has been used before a precipitate takes place, we can learn at once the quantity of chloride present. The volume of the solution required for completing the precipitation shows the proportion of urea, as will be explained presently. The same solution, however, is not used for both these determinations, as, for convenience in reckoning, it is better they should be of different strength. In both cases, it is necessary in the first instance to remove the phosphates from the urine. In order to effect this, a mixture of 1 volume of a cold saturated solution of nitrate of baryta ($BaO.NO^5$) and 2 volumes of saturated baryta-water (BaO.HO) must be prepared. This is the *Baryta-solution.*

Determination of Urea ($C^2H^4N^2O^2$).

38. Preparation of the Solution.—If pure mercury is procured, 71·48 gr. = 1103·93 grs. are dissolved in pure nitric acid with the aid of the heat of a sand-bath. When fumes of nitrous acid (NO^3) cease to be evolved, and a drop of the solution gives no precipitate with chloride of sodium (NaCl), it may be evaporated on a water-bath in the beaker in which it has been prepared, to the consistence of a syrup. It is to be diluted to make a volume of 1,000 C.C. = 15444·00 grs. or about $1\frac{3}{4}$ pints; a few drops of nitric acid (NO^5) being added as often as the solution becomes turbid. In this way it will be made clear again.

If the mercury of commerce is used, a somewhat larger quantity of it is treated with nitric acid as before, but the process is stopped before it is completely dissolved: it is allowed to cool, when crystals of protonitrate of mercury ($Hg_2O.NO^5$) will form. The crystals are thrown on a filter and washed with a little nitric acid. They are to

be boiled with nitric acid, till no more vapours of ni rous acid are given off, and no precipitate is produced if a little is dropped into a solution of chloride of sodium. By evaporating a solution to the consistence of a syrup, pure pernitrate of mercury ($Hg.O.NO^5$) is obtained. This is diluted, but less water added than the solution will probably require. The proportion of mercury it contains is estimated either by sulphuretted hydrogen or by potash; and lastly, it is diluted so as to contain ·772 gr. = 11·92 grs. of peroxide of mercury (HgO) in 10 C.C. = 154·44 grs.

1 C.C. = 15·44 grs. of this solution, made according to either of the above methods, indicates 0·01 gr. = 0·154 gr. of urea.

39. Performance of the Analysis.—In the first place, 40 C.C. = 617·76 grs. of the urine are mixed with 20 C.C. = 308·88 grs. of the baryta solution: the precipitate is filtered, and 15 C.C. = 231.66 grs. of the filtrate are placed in a small beaker. These 15 C.C. contain 10 C.C. of urine. The burette is next filled with the solution, which is added as long as the precipitate is observed to increase. The following test is then applied, to ascertain if a sufficient quantity has been added. A drop of the mixture is removed with a glass rod and placed on a watch-glass. A drop of a solution of carbonate of soda ($Na.O.CO^2$) is then placed near the first, and the two drops are allowed to flow together. If they give a white precipitate, the process is not yet finished; more of the mercury solution must be added, and a drop tested as before, till the two drops, when they coalesce, give a yellow precipitate, which shows an excess of mercury. A second experiment may be made to confirm the first; and lastly, by reading off the number of the C.C. used, the quantity of urea contained in the urine is immediately ascertained. Still there is a correction to be made: the first drops of the solution which produced no precipitate did not combine with, and do not, therefore, correspond to, any of the urea present. This volume must be deducted, or about two cubic centimeters may always be subtracted from the volume of the test-solution used.

Determination of Chloride of Sodium (Na.Cl).

40. Preparation of the Solution.—17·06 gr. = 263·47 grs. of pure mercury are dissolved as before described, and the syrup diluted to a volume of 1,000 C.C. = 15444·00 grs.. or about 1¾ pints, as in the

l- . case. Or, the solution of pernitrate of mercury ($HgO.NO^5$), made from the impure mercury, which has been analysed, is diluted in such proportion, that 10 C.C. of it may contain ·184 gr.=2·84 grs. of peroxide of mercury (HgO).

1 C.C. of this solution answers to ·01 gr.=·154 gr. of chloride of sodium.

41. Performance of the Analysis.—·40 C.C.=617·76 grs. of urine are mixed, as before, with 20 C.C.=308·88 grs. of the baryta solution; 15 C.C.=231·66 grs. of the filtered mixture are placed in a beaker and rendered acid by a few drops of nitric acid. The burette is filled with the test-solution, which is allowed to drop into the beaker, the mixture being continually stirred with a glass rod. As soon as the precipitate at first formed does not disappear by stirring, the operation is finished, and the volume of the solution used is read off. This shows the quantity of chloride of sodium contained in the urine.

With regard to removing the phosphates, in both cases it is to be remarked that, if 1 part of the baryta solution to 2 parts of the urine should not precipitate the whole (a point easily ascertained by adding some of the baryta solution to a few drops of the filtered mixture), more of the baryta solution must be added. This then would somewhat modify the quantity of the mixture to be taken for the test. Suppose it is desired that it should still contain 10 C.C.= 154·44 grs. of urine in it. 17½ C.C.=270·27 grs. of the mixture would be required, if there were 3 parts of baryta solution to 4 parts of urine; 20 C.C.=308·88 grs. would be taken if there were equal parts of baryta solution and urine. More than this will hardly ever be required.

Estimation of Phosphoric Acid.

The estimation of the phosphoric acid by this process is not so exact as those last described, and the greatest care must be taken. A solution of perchloride of iron is added, after the fluid to be tested has first been mixed with a solution of acetate of soda and free acetic acid.

If perchloride of iron be added to a solution containing phosphoric acid, a precipitate of phosphate of iron is produced; at the same time hydrochloric acid, which would redissolve the phosphate, is set free from the perchloride. In order to prevent this, acetate of

soda is added in the first instance; the free hydrochloric acid decomposes the acetate of soda, and acetic acid is set free, in which the phosphate of iron is insoluble.

42. Preparation of the Solutions.—1. *Solution of Perchloride of Iron*—15·556 gr. = 240·24 grs. of pure iron wire are dissolved in pure hydrochloric acid, to which a little nitric acid has been added. The solution is evaporated to dryness on a water-bath, and the residue dissolved in water and diluted to 1,000 C.C. = 15,444 grs. Or a solution of perchloride of iron of moderate strength is prepared. The iron is estimated as peroxide by adding ammonia, and the solution is diluted so as to contain 1·556 gr. = 24·024 grs. of iron in 100 C.C. = 1544·4 grs. In preparing this solution, care must be taken to avoid an excess of hydrochloric acid. One C.C. of this solution indicates ·01 gr. = ·154 grs. of phosphoric acid.

2. *Solution of Acetate of Soda and Acetic Acid.* 20 gr. = 308·88 grs. of crystallised acetate of soda, are dissolved in 100 C.C. = 1544·4 gr. of water, and mixed with 100 C.C. = 1544·4 grs. of acetic acid.

3. *Solution of Ferrocyanide of Potassium.* 1 gr. = 15·44 grs. of ferrocyanide of potassium are dissolved in 100 C.C. = 1544·4 grs. of water.

43. Performance of the Analysis.—100 C.C. = 1544·4 grs. of the urine, are mixed with 10 C.C. = 154·44 grs. of the solution of acetate of soda. The whole is divided into five parts—*a, b, c, d, e*—with a pipette, each part containing 20 C.C. = 308·88 grs. of urine. The burette is filled with the iron solution, and into each of the parts half a C.C. more of the solution is dropped, beginning with six half C.C., so that

a, b, c, d, e, contain
6 7 8 9 10 half C.C.

of the iron solution. They are left for 5—10 minutes, then 3 C.C. = 46·3 grs. of each are filtered into five test-tubes kept ready; and to the filtrates 1 C.C. = 15·4 grs. of the solution of ferrocyanide of potassium is added. If in any of them the deep blue colour of Prussian blue appears, the analysis is finished, and the results may be confirmed by a second experiment. If the colour does not appear, five half C.C. more must be added to each of the parts, so that

a, *b*, *c*, *d*, *e*, now contain
11 12 13 14 15 half C.C.;

and, after standing again, the same test is applied. This process must be repeated until the deep blue colour is obtained. The confirmatory analysis is better made by taking 50 C.C. = 772·2 grs. of urine in each of five beakers, mixing the fluid in each of them with 5 C.C. = 77·22 grs. of the acetate solution, and adding the proportional numbers of half C.C., that are near those indicated by the first experiment. If, for instance, the colour appeared at 12 half C.C., there must be added 28, 29, 30, 31, 32 half C.C., to the different portions of the urine.

44. Estimation of the Earthy Phosphates (*Phosphate of Lime and Magnesia*).—The quantity of phosphoric acid combined with earths (earthy phosphates) may be determined as follows:—First, in one portion of the urine the whole amount of phosphoric acid is estimated as above; in another portion, the earthy phosphates are precipitated by a little ammonia, and the phosphoric acid in combination with alkalies in the filtered fluid is volumetrically determined. The difference between both analyses indicates the quantity of phosphoric acid combined with the earths.

If the urine to be tested is alkaline, and contains a deposit of earthy phosphates, the latter must first be dissolved in as little hydrochloric acid as will take it up.

It is important to familiarise the eye with the tint of colour obtained; and care should be taken always to obtain the same tint.

Determination of the Sulphuric Acid.

45. Preparation of the Solution.—A quantity of crystallised chloride of barium is to be powdered, and dried between folds of blotting-paper. Of this, 30·5 gr. = 471·04 grs. are to be dissolved in 1,000 C.C. = 15444·00 of distilled water.

A dilute solution of *sulphate of soda* is also required.

46. Performance of the Analysis.—100 C.C. = 1544·4 grs. of the urine are poured into a beaker, a little hydrochloric acid added, and the whole placed on a small sand-bath, to which heat is applied. When the solution boils, the chloride of barium test is allowed to flow in very gradually as long as the precipitate is seen distinctly to

increase. The heat is removed, and the vessel allowed to stand still, so that the precipitate may subside. Another drop or two is then added, and so on, until the whole of the SO^3 is precipitated. Much time, however, is saved by using the little apparatus represented in Fig. 32. A little of the fluid is thus filtered clear, poured into a test-tube, and tested with a drop from the burette; this is afterwards returned to the beaker, and more of the test solution added, if necessary. The operation is repeated until the precipitation is complete. In order to be sure that too much of the baryta-solution has not been added, a drop of the clear fluid is added to the solution of sulphate of soda placed in a test-tube. If no precipitate occurs, more *chloride of barium* must be added; if a slight cloudiness takes place, the analysis is finished; but, if much precipitate is produced, too large a quantity of the test has been used, and the analysis must be repeated.

For instance, suppose 27 half-cubic centimeters=208·47 grs. have been added, and there is still a slight cloudiness produced, which no longer appears after the addition of another half-cubic centimeter=7·722 grs. of the solution, we know that between 27 and 28 half-cubic centimeters are required to precipitate the whole of the sulphuric acid present, and 100 C.C.=1544·4 of urine contain between ·135 and ·14 gr.=2·085 and 2·162 grs. of *sulphuric acid.*

Determination of the Sugar.

This method is deduced from the reaction occurring when Trommer's test is employed for testing for grape-sugar. It is well known that grape or diabetic sugar possesses the power of reducing the oxide of copper to the state of yellowish-red sub-oxide.

47. Preparation of the Solution.—An alkaline solution of sulphate of copper is prepared with the aid of *tartaric acid* and *potash.* The former prevents the precipitation of the oxide of copper by the potash. 40 gr. = 617·76 grs. of crystallised sulphate of copper, are dissolved in about 160 C.C.=2471·04 of water. Next, 160 gr.= 2471·04 grs. of neutral tartrate of potash, are to be dissolved in a little water, and from 600 to 700 gr., about 9,500 *grs.* of a solution of soda of 1·12 specific gravity, are to be mixed with it. The solution of the sulphate of copper is added gradually, and the whole

diluted with water to a volume of 1154·4 C.C. = 17828·5 *grs.*; 10 C.C. = 154·4 *grs.* of this solution correspond to ·05 gr. = ·772 *grs.* of sugar.

48. Performance of the Analysis.—10 C.C. = 154·4 grs. of the copper solution are diluted with 40 C.C. = 617·7 grs. of water, and placed in a porcelain dish. About 20 C.C. = 308·8 *grs.* of the urine are diluted with from ten to twenty times their bulk of water, so as to produce, for instance, 300 C.C. = 4633·2 grs. This is to be poured into the burette, and adjusted so as to fill it to the 0° of the scale. The dish with the copper solution is arranged on a sand-bath placed on a tripod stand, at a convenient distance beneath the orifice of the burette. A spirit or gas-lamp is applied until the copper solution approaches the boiling-point, when the urine is allowed to flow in gradually. The mixture is then boiled for an instant, and left for half an hour or more, when the suboxide will have subsided to the lower part. If, after the deposit has settled, the solution possesses a blue tinge, which is easily detected against the white porcelain, the analysis is not finished. More urine is to be added, and the mixture again boiled. This operation is to be repeated as long as any unreduced oxide remains in solution. The process is finished when the supernatant fluid is colourless. The little filtering apparatus described in § 35, and figured in Plate VI., Fig. 32, may be used as soon as the solution is boiled; and, if the whole of the copper has not been precipitated, the clear solution exhibits a blue tint. This saves time in performing the analysis. The proportion of sugar present in the urine is easily calculated.

Suppose 24 C.C. = 370·6 *grs.* of the diluted urine have been required to reduce the 10 C.C. = 154·4 *grs.* of the copper solution, these 24 C.C. contain ·05 gr. = ·772 *grs.* of sugar. But since 300 C.C. of the dilute solution contain only 20 C.C. = 308·8 grs. of the urine, the 24 C.C. contain only 1·6 C.C. = 24·7 *grs.* Therefore, 1·6 C.C. = 24·7 *grs.* of urine contain ·05 gr. = 0·772 *grs.* of sugar, or in 100 C.C. = 1,544 grs. of urine, 3·12 gr. = 48·18 *grs.* of sugar are present.

⁂ The volumetric process of analysis of the urinary constituents is described at greater length in Neubauer and Vogel's "*Analyse des Harns,*" now being translated for the Sydenham Society; and in Dr. Thudichum's "*Treatise on the Pathology of the Urine.*"

49. Davy's Mode of determining Urea.—A long stout glass tube, 12 or 14 inches in length, capable of holding two and a half cubic inches, is closed at one end, and ground perfectly smooth at the open extremity, and graduated to tenths and hundreds of a cubic inch. It is to be filled more than a third full of mercury, and afterwards a measured quantity (from a quarter of a drachm to a drachm) of the urine poured in. Next, the tube is exactly filled with a solution of chlorinated soda (hypochlorite of soda, sodæ chlorinatæ liquor, of the Dublin "*Pharmacopœia*"). Care must be taken to avoid adding too much of the solution, which must be poured in quickly. The orifice of the tube is instantly covered with the thumb; inverted once or twice, to mix the urine and hypochlorite; and placed beneath a saturated solution of salt and water contained in a cup. The mercury flows out, and the solution of salt takes its place; but, being more dense than the mixture of urine and hypochlorite, the latter always remains in the upper part of the tube. The urine is soon decomposed, bubbles of nitrogen escape, and collect in the upper part of the tube. When decomposition is complete, which is known by no more bubbles of gas being evolved, the volume collected is read off, and corrected for temperature and pressure.

One-fifth of a grain of urea should furnish by calculation ·3098 parts of a cubic inch of nitrogen at 60° F. and 30′ Bar. In one experiment, Dr. Davy obtained from the same quantity ·3001; in another, ·3069.

Amount of Urea in an Ounce of Urine, as estimated by Dr. Davy, according to Liebig's Method and his own.

		Liebig's.	Dr. Davy's.
First experiment	..	3·680	3·712
Second experiment	..	5·328	5·472
Third experiment	..	4·976	4·976

("*Dublin Hospital Gazette*," 1855, vol. i., p. 134; Braithwaite's "*Retrospect*," 1854, vol. xxx., p. 109.)

50. Modification of Davy's Method.—Dr. Handfield Jones has found that the results obtained by this plan were not so trustworthy as could be wished, and suggests the following modification. ("*Archives of Medicine*," vol. i., p. 144.)

Lately I have used a bottle, of about six ounces capacity,

with a curved tube of supply, and another to conduct away the gas into a graduated jar (Fig. 34, Plate VI.). *a* is the supply tube; *b*, the out-leading tube; *c*, fluid remaining in curve of supply tube; *d*, mixture in bottle; *e*, receiver to hold and measure the gas generated. After the urine is poured in, the supply tube is washed out with a little water. Of course, at any time, more solution of chlorinated soda (measured quantity) can be added through the supply-tube. I put into the bottle two drachms of urine or more, adjust the out-leading tube to the jar, and pour in, with a pipette, a known bulk of solution of chloride of soda.* This drives over, of course, a corresponding amount of air, and the gas generated, a further amount, so that in the jar I have an amount which – the volume of decomposing fluid = the gas generated. I have ascertained by trial that no alteration of volume takes place when air and nitrogen are mixed. The fluid remaining in the curved supply-tube bars all escape of gas, and it is perfectly easy to empty the bottle afterwards by simply inverting it, when the contents pour out of the gas escape-tube. By shaking the bottle frequently, I can get an experiment finished in about an hour."

"In six trials (some of them being made with a straight tube of supply, going to the bottom of the jar, instead of a curved one), I obtained the following results:—

			Observed.			Calculated.	
(*a*) 2	grains of	urea gave	3·305 C. in.	instead	of	3·098 C. in.	or ·207 +
(*b*) 2	"	"	3·0979	"	"	3·098	or ·0001 –
(*c*) 1·5	"	"	2·3107	"	"	2·323	or ·0123 –
(*d*) 1·3	"	"	2·1313	"	"	2·0137	or ·1276 +
(*e*) 2·5	"	"	3·8498	"	"	3·8725	or ·0227 –
(*f*) 2	"	"	3·0256	"	"	3·098	or ·0724 –

"These are not exact enough to satisfy me, but I do not see any source of fallacy in the mode; and, if in more skilful hands it should prove trustworthy, I think it would have much to recommend it, on the score of facility in previous preparation. The figures have been corrected for temperature and pressure."

* "The solution of chloride of soda used by Dr. Davy is the sol. sod. chlor. of the Dublin '*Pharmacopœia*.' I find that it is not every specimen that serves the purpose well; what I have used lately has been made for me by Mr. Button, Holborn Bars. A fresh solution (filtered) of chloride of lime acts very energetically and quickly, much more so than the sol. sod. chlor., but some carbonic acid is generated and passes over, which complicates the process."

51. Results of Liebig's and Davy's Methods compared.— In some comparative experiments on Liebig's and Davy's methods, Dr. Handfield Jones obtained the following results :—

Urine specific gravity 1,024, full coloured—
By Liebig, gave 15·920 grains of urea per ℥ i.
By Davy, „ 16·640 „ „

Urine specific gravity 1,007, pale, clear—
By Liebig, ℥ i gave 5·250 grains.
By Davy, ℥ i „ 2·636 „

Urine specific gravity 1,029, paleish, lateritious—
By Liebig, ℥ i gave 16·125 grains.
By Davy, ℥ i „ 17·224 „

Urine specific gravity 1,018, albumen, separated—
By Liebig, ℥ i gave 10·500 grains.
By Davy, ℥ i „ 9·760 „

Dr. Von Bose has also estimated the proportion of urea in the same specimen of urine, by the two methods. Ten cubic centimeters of six different specimens of urine gave the following results :—

	Liebig's Method.	Davy's original Method.
1	·365 gr.	·310 gr.
2	·335 „	·260 „
3	·370 „	·295 „
4	·225 „	·269 „
5	·247 „	·231 „
6	·220 „	·253 „

⁂ The apparatus required for the volumetric analysis of urine may obtained of Messrs. Griffin, Bunhill Row, E.C.; Messrs. Bullock and Reynolds, 3, Hanover Street, W. ; and at most operative chemists and philosophical instrument makers. The graduated tubes may also be obtained of Messrs. Negretti and Co., Holborn Hill.

CHAPTER III.

Examination and Preservation of Urinary Deposits. *Collecting Urine for Microscopical Examination—Period when the Urine should be examined—Removal of the Deposit from the Vessel containing it—of Collecting a very small quantity of a Deposit from a Fluid—Magnifying Powers required in the Examination of Urine—of the Chemical Examination of Urinary Deposits—Examination of the Deposit in the Microscope—of placing the Deposit in the Preservative Fluid—Refractive Power of the Medium in which Deposits are mounted—Media in which Urinary Deposits may be preserved—of keeping the Deposit for subsequent Inquiries—of preserving Deposits permanently—Mucus, Epithelium, Fungi, and Vegetable Growths—Spermatozoa—Casts—Pus—Phosphates, Urates, Blood Corpuscles, Uric Acid, Cystine, Oxalate of Lime—on preserving Crystalline Substances which are more or less soluble in Water.* Of Extraneous Matters of Accidental Presence—*Larvæ of the Blow-fly—Hair—Cotton and Flax Fibres—Portions of Feathers—Silk—Fibres of Deal from the Floor—Starch Granules—Portions of Tea Leaves—Milk—Sputum—Epithelium from the Mouth—Vomit.*

Examination of Urinary Deposits.

The examination of urinary deposits is now a subject of such great importance, and the advantages derived from it are so generally admitted, that I need scarcely refer to its value, in assisting us to form a diagnosis in many cases of disease. Within the last fifteen or twenty years, the investigation of urinary deposits has been much simplified, and the results obtained by the conjoint use of the microscope and chemical analysis have been so accurate and decided, that the nature of the greater number of deposits has been definitely determined.

When the student commences to examine urinary deposits for the first time, he will doubtless meet with many difficulties; and in some specimens which he examines, he will perhaps discover no deposit whatever; whilst in examining others, the whole field of the microscope is seen to be occupied by substances of various shapes and colours, the nature of which he will be unable to ascertain. Many of the substances which lead to this difficulty have obtained entrance into the urine accidentally; and the observer should therefore be warned against mistakes easily made, which are serious, and may bring great discredit upon his powers of observation. Portions of hair have been mistaken for casts of the renal tubes; starch-granules for cells; vegetable hairs for nerve fibres; casts for the basement membrane of the uriniferous tubes; and many other substances of extraneous origin, such as small portions of woody fibre, pieces of feathers, wool, cotton, etc., often take the form of some of the urinary deposits, and to a certain extent resemble the drawings given of them in their general appearance, so as to mislead the student in his inferences, and retard his progress in investigation.

52. Collecting Urine for Microscopical Examination.—Urine, which is to be submitted to examination, should be collected in considerable quantity, in order to obtain sufficient of the *deposit* for examination. In many instances, the amount of sediment, even from a pint of urine, is so small that, without great care in collecting, it may be altogether passed over. The amount of deposit from a measured quantity of urine should always be roughly noted. The space occupied by the deposit may be compared with the total bulk of the fluid, and we may say the deposit occupies a fifth, a fourth, half the bulk of the urine, etc.

Bottles used for carrying specimens of urine should be made of white glass, with tolerably wide mouths, and capable of holding at least four ounces; but if the sediment only of the urine is required, the clear supernatant fluid may be poured off, after the urine has been allowed to stand for several hours, and the remaining deposit may then be poured into small bottles of an ounce capacity, or even less. The only objection to this latter mode of collecting urine is, that no estimate of the *amount* of sediment deposited by a given quantity of urine can be formed. The bottles may be arranged in a case capable of containing two, four, or six. They may be obtained

of Messrs. Weiss, in the Strand; Mr. Highley, 70, Dean Street, W.; Mr. Matthews, near King's College Hospital; and other instrument makers.

53. Period when the Urine should be Examined.—In all cases the urine should, if possible, be examined within a few hours after its secretion; and, in many instances, it is important to institute a second examination after it has been allowed to stand for twenty-four hours or longer. Some specimens of urine pass into decomposition within a very short time after they have escaped from the bladder; or the urine may even be drawn from the bladder actually decomposed. Under these circumstances, we should expect to find the secretion highly alkaline, having a strongly ammoniacal odour, and containing crystals of triple phosphate, with granules of earthy phosphate; and upon carefully focussing, numerous vibriones may generally be observed. In other instances, the urine does not appear to undergo decomposition for a considerable period, and may be found clear, and without any deposit, even for weeks after it has been passed.

In those cases in which *uric acid* or *octohedral crystals of oxalate of lime* are present, the deposit increases in quantity after the urine has stood for some time. These salts are frequently not to be discovered in urine immediately after it is passed, but make their appearance in the course of a few hours. The deposition of uric acid depends upon a kind of acid fermentation, which has been the subject of some beautiful investigations by Scherer (§ 119).

In order to obtain sufficient of the deposit from a specimen of urine for microscopical examination, we must place a certain quantity of the fluid in a conical glass (§ 12); in which it must be permitted to remain for a sufficient time to allow the deposit to subside into the lower part.

54. Removal of the Deposit from the Vessel containing it.—In order to remove the deposit from the lower part of the vessel in which it has subsided, the upper end of the *pipette* is to be firmly closed with the forefinger, the tube being held by the thumb and middle finger. Next, the lower extremity is to be plunged down to the bottom of the deposit. The forefinger may now be raised very slightly, but not completely removed, and a few drops of the fluid with the deposit slowly pass up into the tube (Fig. 9, Plate II.).

When a sufficient quantity for examination has entered, the forefinger is again pressed firmly upon the upper opening, and the pipette carefully removed. A certain quantity of the deposit is now allowed to flow from the pipette on to the glass slide or cell, by gently raising the forefinger from the top. It is then covered with the thin glass cover, and subjected to examination in the usual way. Dr. Venables recommends that the deposit should be obtained by inverting a corked tube into which the urine has been previously poured. A small quantity of the deposit adheres to the cork, and may be removed to a glass slide; but, as a general rule, the plan above described will be found efficient.

55. Of Collecting a very small quantity of a Deposit from a Fluid.—When the quantity of deposit is very small, the following plan will be found of practical utility. After allowing the lower part of the fluid which has been standing, to flow into the pipette, as above described, and removing it in the usual manner, the finger is applied to the opening, in order to prevent the escape of fluid when the upper orifice is opened by the removal of the finger. The upper opening is then carefully closed with a piece of cork. Upon now removing the finger from the lower orifice, the fluid will not run out. A glass slide is placed under the pipette, which is allowed to rest upon it for a short time. It may be suspended with a piece of string, or supported by the little retort stand. Any traces of deposit will subside to the lower part of the fluid, and must of necessity be collected in a small drop upon the glass slide, which may be removed and examined in the usual way.

Another plan is to place the fluid, with the deposit removed by the pipette, in a narrow tube, closed at one end, the bore of which is rather less than a quarter of an inch in diameter. This may be inverted on a glass slide, and kept in this position with a broad elastic India-rubber band. The deposit, with a drop or two of fluid, will fall upon the slide, but the escape of a further quantity of fluid is prevented by the nature of the arrangement, which will be understood by reference to Plate VI., Fig. 33.

56. Magnifying Powers required in the Examination of the Urine.—Urinary deposits require to be examined with different magnifying powers. The objectives most frequently used are the inch and the quarter of an inch. The former magnifies about 40

diameters (× 40); the latter from 200 to 220 (× 200, × 220). Large crystals of uric acid may be readily distinguished by the former, but crystals of this substance are sometimes so minute that it is absolutely necessary to use high powers. Octohedra of oxalate of lime are frequently so small that they cannot be seen with any power lower than a quarter; and, in order to bring out the form of the crystals, even higher object-glasses than this are sometimes necessary. Spermatozoa may be seen with a quarter, but they then appear very minute. In these cases, an eighth of an inch object-glass, which magnifies about 400 diameters (× 400), will be of advantage. The casts of the tubes, epithelium, and the great majority of urinary deposits, can, however, be very satisfactorily demonstrated with a quarter of an inch object-glass.

A deposit, the nature of which is doubtful, should be subjected to examination in fluids possessing different refractive powers, such as water, serum, mucilage, glycerine, turpentine, Canada balsam, etc.

57. Of the Chemical Examination of Urinary Deposits.—In the investigation of those deposits which are prone to assume very various and widely different forms, such as uric acid, it will often be necessary to apply some simple chemical tests, before the nature of the substance under examination can be positively ascertained.

Suppose for instance, a deposit which is found, upon microscopical examination, not to possess any characteristic form, be suspected to consist of uric acid, or of an alkaline urate, it is only necessary to add a drop of solution of potash, which would dissolve it, and then excess of acetic acid, to obtain the crystals of uric acid in their well-known rhomboidal form. Other chemical tests which should be considered necessary may be applied afterwards.

When it is requisite to resort to chemical reagents, a drop of the test-solution is to be added to the deposit, which is placed in the cell, or upon the glass slide. The little bottles described in § 34 will be found most convenient for this purpose. If necessary, heat may be applied to the slip of glass by a spirit-lamp, and, with a little practice, the student will soon be able to perform a qualitative analysis of a few drops of urine, or of a very small portion of a deposit.

58. Examination of the Deposit in the Microscope.—The drop of urine with the deposit is to be placed in a thin glass cell, or

in one of the animalcule cages (§ 30, Plate V., Figs. 24, 26). These instruments will be found convenient for examining urinary deposits, as a stratum of fluid of any degree of thickness can be very readily obtained. A simple form of compressorium may be also conveniently used for the examination of urinary deposits (Plate VI., Fig. 35).

Various parts of the specimen are to be brought into the field of the microscope. It is better to examine the object as regularly as possible, commencing on one side, and moving it up and down, until the whole has been traversed. After one specimen has been examined, and the nature of its contents noted, another may be treated in a similar manner. Specimens should be taken from the deposit at different levels, for while some deposits soon sink to the bottom, others are buoyed up, as it were, either by the small quantity of mucus which the urine contains, as is the case with small crystals of oxalate of lime, or by the flocculent nature of the deposit itself.

As each part of the deposit is brought under the field of the microscope, the observer should endeavour to recognise every object as it passes under his view. This, however, will for some time be found a matter of considerable difficulty, arising partly from the number of deposits which commonly occur together, and partly from the very various forms which many of these substances are liable to assume, but chiefly, I believe, from the great number of substances of accidental presence which are found in almost every specimen of urine subjected to examination; especially in urine obtained from the wards of a hospital, upon which the first microscopical observations are usually made. Accurate copies of the different urinary deposits, drawn on the stone with the aid of the glass reflector (§ 33), are represented in the plates of the "*Illustrations of Urine, Urinary Deposits, and Calculi.*"

I cannot too strongly recommend the observer to sketch the appearances of the different deposits which come under his notice. He will by so doing become familiar with the characters of urinary deposits much more quickly than if he merely instituted a hasty and imperfect examination. The methods of obtaining sketches of the exact size of the image in the microscope, are described in "*How to Work with the Microscope.*" (See also § 33.)

On the Preservation of Urinary Deposits as Permanent Microscopic Objects.

A desire has been generally expressed that a series of the most important urinary deposits should be kept for sale, so that practitioners might have an opportunity of readily obtaining named specimens, with which the deposits that from time to time fall under notice might be compared, and their nature recognised. Persons who prepare and sell microscopic objects have experienced great difficulty in preserving urinary deposits satisfactorily; and many specimens which have been purchased have been found to lose their characters after a few months, and have soon become quite useless objects. Feeling strongly the real practical value of preparations of this kind, it seems to me very desirable that a few rules with regard to the preservation of urinary deposits should be laid down; and I therefore propose to allude briefly to the different plans which I have found to succeed best. I hope that, shortly, there will be no difficulty in obtaining series of well-mounted and illustrative specimens.* At the same time, any one attending hospital practice, who has a little time at his disposal, can, without much trouble, prepare such preparations for himself.

The different characters of urinary deposits render necessary different plans of preservation. It is, therefore, desirable to consider the nature of the deposit before we attempt to preserve it. Some deposits may be preserved *dry*, others may be mounted in *Canada balsam*. A certain number exhibit their characters very well if preserved in *glycerine*, while many can only be kept in certain *aqueous fluids*.

59.—Of placing the Deposit in the Preservative Fluid.— After the deposit has been allowed to settle in a conical glass, the supernatant fluid is to be poured off; and if it is to be mounted *in fluid*, a quantity of the preservative solution, equal in bulk to the urine and deposit that remain, is to be added. After the deposit has again settled, the fluid is to be poured off and replaced with an equal portion of fresh preservative solution. In this way the deposit is washed clean, and properly impregnated with the preservative fluid.

* Specimens of urinary deposits may be obtained of Messrs. Smith and Beck, Coleman Street, City; Mr. Tennant, 149, Strand; and Mr. Matthews, surgical instrument maker, Carey Street, Lincoln's Inn Fields.

When preparations are to be preserved in a fluid medium, a small shallow water-tight cell is to be used. The specimen and its preservative fluid being placed in the cell, the thin glass is applied, and the cover cemented in its place with the aid of Brunswick black or other cement. ("*How to Work with the Microscope.*") In washing urinary deposits prior to mounting them, it is often necessary to add some compound to the water used for this purpose, in which they are known to be insoluble; and sometimes it is desirable to add some substance to increase the density of the fluid; for which purpose, certain salts, syrup, or glycerine may be employed, according to circumstances. Many deposits, although soluble to some extent in pure water, are quite insoluble in a weak acid; others are insoluble in a weak alkali or in certain saline solutions. Again, it is sometimes desirable to separate certain substances in the deposit from others, and this may be effected by special chemical solutions which have the power of acting on the one and not upon the other; or, in cases where one is more dense than the other, by agitating the deposit with water, and, after allowing time for the heavier deposit to settle, pouring off the lighter one into another vessel, to subside there. From this, it may be collected in the usual way.

60.—Urinary Deposits preserved as Dry Objects.—If the preparation is to be preserved as a *dry object*, water is to be added in the first place; and a portion of the deposit, which has thus been carefully washed, is to be removed with the aid of a pipette to the glass slide, and the fluid allowed to evaporate, the whole being covered by a bell-jar, and placed over a dish of strong sulphuric acid. When dry, it is to be protected from dust by a thin glass cover. The glass cover is easily prevented from pressing upon the preparation by interposing a thin piece of paper or cardboard; or a thin India-rubber ring, which may be easily fixed to the glass slide and thin glass cover, by a little gum made into a thick paste with whiting, may be used.

61.—Preservation in Canada Balsam.—If the specimen is to be mounted in *Canada balsam* or turpentine, it is to be dried in the manner just described, warmed slightly, wetted with turpentine or balsam, and mounted with the usual precautions. ("*How to Work with the Microscope.*")

62.—Refractive Power of the Medium in which Deposits are Mounted.—The appearance of objects in the microscope depends very much upon the medium in which they are immersed; and many structures are so altered in their character by different media, that they would hardly be recognised as the same object. It may be said, generally, that the darker the object, and the more dense its structure, the higher should be the refractive power of the medium in which it is mounted—thus the dark-coloured uric acid, or the thick spherical crystals of carbonate of lime, and the dumb-bells of oxalate of lime, exhibit their structure to the greatest advantage when mounted in the highly refracting *Canada balsam*, or in *strong syrup* or *glycerine*, while the beautifully transparent octohedra of oxalate of lime would be scarcely visible in these media, and require to be mounted in an aqueous fluid which possesses a lower degree of refractive power. Many of these objects, when mounted dry, appear quite dark, and scarcely exhibit any structure at all, in consequence of the great difference in the refracting power of their substance, and the air by which they are surrounded. From what has been said, it will be evident how important it is to examine the same object in different media—in fact, it is quite impossible to form an idea of the real structure of many specimens, without proceeding in this manner. ("*How to Work with the Microscope*," p. 59; and "*The Microscope in its Application to Practical Medicine*," second edition, §§ 74, 89, and 90.)

63.—Media in which Urinary Deposits may be Preserved.—Urinary deposits may be mounted in *air*, in *turpentine*, *oil*, or *Canada balsam;* in *glycerine*, in *gelatine and glycerine*, in *solution of naphtha and creasote*, in *certain saline solutions*, in *weak spirit*, and in some other aqueous solutions, which will be alluded to. The *glycerine* which I use is "*Price's patent glycerine*," diluted with one third part, or more, of water. In making more dilute solutions of glycerine, it is well to employ camphor water, as this prevents the formation of fungi. Many urinary deposits may be preserved in strong glycerine, if care be taken to increase the density of the solution gradually, and sufficient time be allowed for the deposit to be thoroughly permeated with the fluid. The best plan is to add a little glycerine to the deposit which has been allowed to collect in the conical glass. After the deposit has settled, pour off the

supernatant fluid and add fresh glycerine. Repeat the same process two or three times. I have kept specimens preserved in strong glycerine for ten years with very slight change; and probably they will retain their character for a much longer time than this.

The composition of the naphtha and creasote fluid, above referred to, is as follows:—

Solution of Naphtha and Creasote.

Creasote	3 drachms.
Wood naphtha......................	6 ounces.
Distilled water	64 ounces.
Chalk, as much as may be necessary.	

Mix first the naphtha and creasote, then add as much prepared chalk as may be sufficient to form a smooth thick paste; afterwards add, very gradually, a small quantity of the water, which must be well mixed with the other ingredients in a mortar. Add two or three small lumps of camphor, and allow the mixture to stand in a lightly covered vessel for a fortnight or three weeks, with occasional stirring. The almost clear supernatant fluid may then be poured off and filtered, if necessary. It should be kept in well corked or stoppered bottles.

64. Of keeping the Urinary Deposit for subsequent Inquiries.—In cases where it is desirable to retain a certain quantity of the deposit in the preservative solution for subsequent examination, or for the purpose of making more preparations, it should be kept in a small glass tube, with a tight-fitting cork, and carefully labelled. Most urinary deposits may be kept for a longer time in this manner than if mounted in thin cells. I propose now to describe briefly the various plans adapted for the preservation of urinary deposits which I have found to succeed best.

Preservation of Special Deposits.

65. Mucus.—It is very difficult to preserve the character of the so-called "mucus corpuscles," or imperfectly formed epithelial cells, nuclei, and granules, which constitute the slight flocculent deposit met with in healthy urine, and termed "mucus." The naphtha and creasote solution is best adapted for the purpose, and it is desirable to place the specimen in a cell about the twentieth of an inch in depth.

66. Epithelium.—The different varieties of epithelium are easily preserved, although, after the lapse of some time, minute oil globules make their appearance in them. They may be kept in naphtha and creasote fluid, to which one-fourth of its bulk of glycerine has been added. It is well to put up specimens of epithelium from the urethra, bladder, ureter, and pelvis of the kidney, removed from the organs of a healthy man who has been killed accidentally. They should be mounted in very thin cells. Specimens of the epithelium from the vagina, which can generally be obtained from the urine of females, should also be preserved.

67. Vegetable Growths: Fungi.—I have found that fungi may be preserved most satisfactorily in glycerine, for although they appear somewhat more transparent in this fluid than in urine, they preserve their general character better than when immersed in other preservative fluids. It is necessary to add weak glycerine in the first instance, and to increase the strength gradually, otherwise the fungi become collapsed, owing to the great density of the strong solution. A solution composed of equal parts of water and Price's glycerine is sufficiently strong to preserve fungi. I have not been able to preserve specimens of sarcinæ which I have met with on two or three occasions in the urine, probably in consequence of their extreme delicacy. The sarcinæ which are from time to time met with in vomit keep perfectly well, and preserve their recent characters in glycerine.

68. Spermatozoa are sometimes mounted in the dry way; but although their general form is preserved, their refractive power and transparent appearance are so different from what is observed when they are immersed in urine, that little is gained from such preparations. Spermatozoa keep very well in glycerine, although they appear rather more faint than in an aqueous fluid. They should be examined with the *eighth of an inch object-glass* (× about 400); but when the eye of the observer has become familiar with the general appearances, they may be readily recognised with a quarter of an inch object-glass (× about 200).

69. Casts.—It is not difficult to preserve the character of some varieties of casts. The transparent casts often become covered with numerous minute granules and oil globules, and their character much altered. Granular casts and epithelial casts often keep very well in

the naphtha and creasote solution; but altogether I prefer glycerine, with one-third part of water. Although, in many instances, the cells they contain are altered, and oil globules appear much more transparent than when in urine, this alteration in character may be easily allowed for. The specimens in glycerine, of course, keep admirably. I have some specimens of large waxy casts and epithelial casts which have been kept in the naphtha and creasote solution for upwards of seven years, and still preserve their characters well. Some casts may also be preserved in gelatine and glycerine, care being taken that the mixture is not made too hot. Casts may be coloured slightly with an ammoniacal solution of carmine, and preserved in glycerine. The very transparent casts, which are hardly visible under ordinary circumstances, can thus be demonstrated very clearly and preserved. Any nuclei in the cast are intensely coloured by the carmine.

70. Pus.—Recent specimens of pus may be so readily obtained that it is hardly necessary to attempt to preserve the corpuscles permanently. Their characters alter so much in all the aqueous preservative fluids that I have tried, that after they have been put up for some time, it would be difficult to recognise the nature of the preparation. I have, however, succeeded in preserving some specimens of pus in glycerine by observing the precautions mentioned in § 63. Cancer cells, which are sometimes found in very large quantities in the urine in cases of cancer of the bladder, may be preserved in the same manner. I have several specimens which have been mounted for five or six years.

71. Phosphates.—The phosphate of lime, in its amorphous form, in globules, and minute dumb-bells, is easily preserved in weak spirit, naphtha and creasote fluid, or glycerine; but the character of the crystals of the triple or ammoniaco-magnesian phosphate could not be retained in this solution. As is well known, this salt is quite insoluble in solutions of ammoniacal salts, and these make the best preservative solutions for it. Crystals of triple phosphate may be kept for any length of time, with their smooth surfaces and their lustre unimpaired, in distilled water, to which a little chloride of ammonium has been added. Phosphate of lime and the stellar form of triple phosphate may be dried carefully, and mounted in Canada balsam; but, of course, the appearance of the crystals is a good deal altered.

72. Urates.—As the urates are so commonly met with, and as they are generally deposited in the form of granules, there is scarcely any need of mounting them as permanent objects. If desired, however, deposits of this kind may be preserved by adding a little naphtha and creasote fluid to the deposit, which should be left in it for a considerable time before it is put up. Urates which crystallize in small spherical masses, as often occur in the urine of children, and more rarely in irregular branched processes, may be preserved very well in Canada balsam, or, if preferred, they may be kept in the naphtha and creasote fluid.

73. Blood Corpuscles become more or less altered in most preservative fluids. I think that those which I have mounted in glycerine (one part water to three parts of glycerine) have undergone the least change.

74. Uric Acid Crystals are easily preserved as permanent objects. The usual plan is to mount them in Canada balsam. They should be washed, in the first instance, with a little water, to which a few drops of acetic acid have been added. When pretty clean, they may be placed upon a glass slide, with the aid of a pipette, and the greater quantity of the fluid absorbed with a small piece of bibulous paper. After the crystals have been properly arranged on the slide with a needle, they may be dried, by exposure under a bell jar over a dish containing sulphuric acid. When quite dry, they may be moistened with a drop of turpentine, and mounted in Canada balsam. In this operation, a very slight heat should be employed, otherwise the crystals will become cracked in all directions, and more or less opaque. Uric acid crystals, as a general rule, do not keep well in glycerine. In cases where we wish to preserve other substances in the deposit as well as uric acid crystals, the naphtha and creasote fluid will be found to answer very well. I have some preparations mounted in this manner, which were put up six or seven years ago.

75. Cystine.—Crystals of cystine may be preserved in Canada balsam, the same care being taken in mounting them as mentioned under uric acid, or they may be kept very well in distilled water, or in the naphtha and creasote fluid, to which a little acetic acid has been added.

76. Oxalate of Lime.—Both the octohedra and dumb-bells may be preserved for many years in the naphtha and creasote solution and also in glycerine. The octohedra look very transparent in the latter fluid. The dumb-bells may also be mounted in Canada balsam, in which medium the octohedra are almost invisible. When required for polarising, these and other crystals should be put up in balsam.

77. On Preserving Crystalline Compounds obtained from Urine.—It is exceedingly difficult to preserve many of the crystalline substances obtained from urine in a moist state; but several of them form beautiful microscopic objects when carefully dried. *Urea, nitrate of urea, oxalate of urea, creatine, creatinine, alloxan, hippuric acid, murexid,* and many others, may be kept as permanent objects in this manner. In order to prepare them, it is better to cause them to crystallize upon a glass slide; allow the mother liquor to drain off, and immediately place the slide under a bell-jar over sulphuric acid. Sometimes the crystals may be made in a small evaporating basin, and when drained and dried, a portion of them may be removed to a glass cell, and covered with a piece of thin glass to exclude the dust. Many crystals may be examined and preserved for a considerable time in their own mother liquor, especially when they are very slightly soluble in fluid; but, as a general rule, this plan does not answer very satisfactorily, for, independently of the escape of the fluid from the edges of the cell, a few of the largest crystals grow still larger at the expense of the smaller ones, and the beauty of the specimen is destroyed. The different forms of these crystals, as they appear in the microscope, are given in the "*Illustrations of Urine, Urinary Deposits, and Calculi,*" "*Urine,*" Plates I. to IX.; *see* also "*The Microscope in its Application to Practical Medicine,*" chap. ix., p. 292.

Of Extraneous Matters.

78. Importance of recognising Extraneous Matters.—In the microscopical examination of urinary deposits, the observer often meets with substances the nature and origin of which he cannot readily determine. This is due, in many instances, to the presence of bodies which have fallen in accidentally, or which have been placed in the urine for the express purpose of deceiving the practitioner. The importance of recognising matters of an extraneous

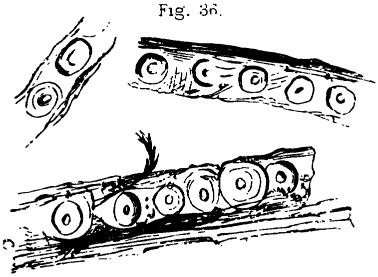
origin can scarcely be sufficiently dwelt upon, for until the eye becomes familiar with the characters of these substances, it will obviously be quite impossible to derive such information from a microscopical examination of the urine as will enable the observer to distinguish between those bodies, whose presence denotes the existence of certain morbid conditions, and certain matters which have accidentally found access, which, clinically speaking, may be entirely disregarded. Practitioners who use the microscope for investigating the nature of urinary deposits, will derive advantage from subjecting many of the substances referred to separately to microscopical examination, so that when met with in the urine, their nature may be at once recognised. As most of the undermentioned substances are readily obtained and easily subjected to examination, a brief notice of their character will be sufficient. Attention should be especially directed to the fact of the frequent occurrence of many of these extraneous substances in urine, and the observer should particularly notice those characters in which they resemble any insoluble substance derived from the bladder or kidney, or deposited from the urine.

The following are some of the most important of these extraneous matters which have fallen under my own notice:—

Human hair.	**Milk.**
Cat's hair.	**Oily matter.**
Blanket hair.	**Potato starch.**
Worsted.	**Wheat starch.**
Wool.	**Rice starch.**
Cotton and flax fibres.	**Tea leaves.**
Splinters of wood.	**Bread crumbs.**
Portions of feathers.	**Chalk.**
Fibres of silk.	**Sand.**

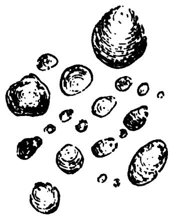
The microscopical appearances of some of these substances are given in Plate VIII., Figs. 36, 37, and 38, *see* also Plates I., II., and III., Figs. 1 to 16, of the "*Illustrations of Urine, Urinary Deposits and Calculi.*" It would hardly be believed what curious and unexpected substances are sometimes found in the urinary secretion. Some time since, a specimen of urine was sent for examination, which contained several white bodies, about half-an-inch in length, like maggots. Upon microscopical examination, I found that these con-

Fig. 36.



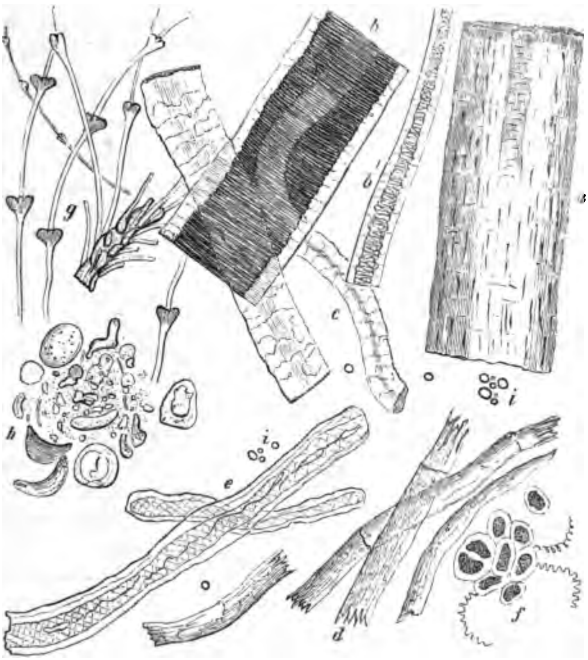
§ 84. × 215.

Fig. 37.



§ 85. × 215.

Fig. 38.



§§ 80, 81, 82, 85, 86, 87 × 215.

To face page 38.

tained tracheæ, and they ultimately proved to be *larvæ of the blowfly*, although it had been stoutly affirmed that they had been passed by the patient from his bladder.

79. Sesquioxide of Iron.—A few years ago, Dr. Stewart informed me that a man had brought some urine to him for examination, with a thick, brick-red deposit, which was analysed by Mr. Taylor, and proved to consist of sesquioxide of iron. The urine containing this deposit, was of specific gravity 1·011; and upon the addition of ammonia, a brown flocculent precipitate (hydrated sesquioxide of iron) was thrown down. Dr. Stewart tells me, that a considerable quantity of the powder (jeweller's rouge, or sesquioxide of iron) remained suspended in the urine after it had stood for many hours, and that the fluid was still turbid after having been passed through a double filter. The man who brought this urine has been endeavouring for some time to impose upon different hospital physicians.

80. Hair of various kinds is very frequently found amongst urinary deposits, but, as its microscopical appearance is so well known, it is not necessary to enter into a description of the characters by which it may be distinguished. The varieties of hair most commonly found are human hair, blanket hair, and cat's hair. Not unfrequently portions of coloured worsted will be met with; but the colour alone will often remove any doubts with reference to the nature of the substance. Portions of human hair are sometimes liable to be mistaken for transparent casts of the uriniferous tubes, which are quite destitute of epithelium or granular matter, and which present throughout a homogeneous appearance. The central canal, with the medullary cells within it, in many cases, will be sufficient to distinguish the hair from every other substance likely to be mistaken for it (Plate VII., Fig. 38*a*); but sometimes this cannot be clearly made out, and the marks on the surface may be indistinct; when attention must be directed to its refracting power, well defined smooth outline, and also to the sharply truncated or fibrous ends, or to its dilated club-shaped extremity in the case of the hair-bulb. In the latter points, small portions of hair will be found to differ from the cast, for this latter does not refract so strongly; the lines on each side are delicate, but well defined, and the ends are seldom broken so abruptly as in the case of the hair. Cat's hair (Fig. 38*b*) can scarcely be mistaken for any urinary deposit with which I am acquainted,

and its transverse markings will serve at once to distinguish it with certainty. ("*Illustrations*," Plate I., Figs. 1, 2, 3.)

81. Cotton and Flax Fibres are very often found in urine (Fig. 38 *d*, *e*). When broken off in very short pieces, they may be mistaken for casts; but the flattened bands of the former (*e*), and the somewhat striated fibres of the latter (*d*), will generally be found sufficiently characteristic. ("*Illustrations*," Plate III., Fig. 16; Plate I., Fig. 4.)

82. Portions of Feathers are often detected in urinary deposits upon microscopical examination, and are derived, no doubt, from the bed or pillow (Fig. 38*g*). The branched character of the fragments will always enable the observer to recognise them with certainty. ("*Illustrations*," Plate III., Fig. 14.)

83. Pieces of Silk are not unfrequently present, but these can scarcely be mistaken for any substance derived from the kidney. Their smooth glistening appearance and small diameter, at once distinguish them from small portions of urinary casts, and their clear outline and regular size from shreds of mucus, &c.

84. Fibres of Deal from the Floor.—Of all the extraneous matters likely to be met with in urine most calculated to deceive the eye of the observer, none are more puzzling than the short pieces of single fibres of deal (Plate VII., Fig. 36). In hospitals, where the floor is uncovered, and frequently swept, portions of the fibres of the wood are detached, and being light, very readily find their way into any vessel which may be near. In fact, these fibres enter largely into the composition of the dust which is swept up. I was familiar with the appearance of these bodies for a long time before I ascertained their nature; for, although the peculiar character of coniferous wood is sufficiently well marked, when only very small portions are present, and in a situation in which they would scarcely be expected to be met with, their nature may not be so easily made out. Often only two or three pores may be seen, and not unfrequently these are less regular than usual, in which case they may be easily mistaken for a small portion of a cast with two or three cells of epithelium contained within it. I have very frequently met with these fibres amongst the deposit of various specimens of urine which have been

obtained from private as well as from hospital patients. ("*Illustrations*," Plate III., Fig. 15.)

85. Starch Granules are very commonly found in urinary deposits, and indeed in all matters subjected to microscopical examination; usually their presence is accidental, but large quantities of starch have often been added for purposes of deception. Their true nature may be discovered, either by their becoming converted into a jelly-like mass on being boiled with a little water in a test-tube, by their behaviour upon the addition of free iodine, or by their well-defined microscopical characters. Certain cases have been recorded, in which it was maintained that the starch granules present in the urine had passed from the kidney; but it need scarcely be said that such an origin is very improbable, if not quite impossible. In cases where due care has been taken to prevent the access of starch globules after the urine had been passed, none were observed. We learn by experience that we can seldom receive the statements of patients upon these matters, however positive they may be. They often deceive themselves as to the actual occurrence, in their own case, of what never has occurred and never can occur. The three kinds of starch most likely to be met with in urine are potato starch (Plate VII., Fig. 37), wheat starch (Fig. 38*h*), and rice starch. They are readily distinguished by microscopical examination. Small portions of potato, or pieces of the cellular network in which the starch globules are contained, have been occasionally met with. Under the head of starch may also be included bread-crumbs (Fig. 38*h*), which are very commonly present in urine, and have a very peculiar appearance, which may be so easily observed, that a description would appear superfluous. Many of the starch-globules will be found cracked in places, but their general characters are not otherwise much altered. ("*Illustrations*," Plate II., Figs. 6, 7, 8, 9, 10, 11.)

86. Portions of Tea-leaves are occasionally found in urine (Fig. 38*f*). The beautiful structure of the cellular portions, and the presence of minute spiral vessels, distinguish this from every other deposit of extraneous origin. A small piece of a macerated tea-leaf will be found to form a most beautiful microscopic object. ("*Illustrations*," Plate I., Fig. 5.)

87. Milk and certain Colouring Matters are sometimes purposely added to urine; and it is often difficult to make out whether they have been added with the intention of deceiving us, especially as urine is sometimes met with, having all the appearance of milk (chylous urine); and certain colouring matters, such as logwood and indigo, when taken into the stomach may be absorbed by the vessels, and eliminated from the system in the urine. A form of Indigo, there can be no doubt, is actually produced in the urine.

Urine, to which milk has been added, can be distinguished from the so-called chylous or milky urine by its microscopical characters. The presence of small oil-globules, with a well defined dark outline, can always be detected in milk by the aid of the microscope, while in chylous urine nothing but a great number of very minute and scarcely visible granules, composed of fatty matter, can be made out. ("*Illustrations,*" Plate III., Fig. 13.) I have had several specimens of milky urine sent to me for examination, upon the supposition that they were examples of chylous urine, and in some the milk had been added in sufficient quantity to yield a firm curd, after standing for a day or two, and a precipitate upon the addition of acetic acid. Where only a very small quantity of milk is added, the difficulty of deciding positively is greatly increased. The globules are, I believe, characteristic. Some cases of chylous urine are recorded, in which the fatty matter existed in distinct globules; and therefore we cannot unfortunately lay it down, that in *all* cases of this disease, the fatty matter is in a *molecular state.* In the six or seven true cases of chylous urine, which have been brought under my own notice, the fatty matter was in this very minute state of division; and in several supposed ones, in which *oil-globules* were present, they were proved to have resulted from the addition of milk for the purpose of deception, or from the use of an oiled catheter. The observer should also be familiar with the appearance of oil-globules under the microscope (Fig. 12).

88. Sputum: Epithelium from the Mouth: Vomit. It must be remembered, too, that epithelium from the mouth is often found in urine. All the cells met with in sputum are occasionally found, and a vast number of different substances, which are rejected by vomiting, are from time to time detected. The observer must not be surprised at finding now and then some well defined elementary fibres

of striped muscle. It is most difficult to prevent these different substances from being mixed with the urine. They often cause the microscopist great trouble—and especially at first, before the eye has become quite familiar with their appearance, they are likely to give rise to the greatest confusion in descriptions of microscopical appearances. For the microscopical characters of the substances present in sputum and vomit, I must refer to "*The Microscope in its application to Practical Medicine*," and the Plates in the third part of "*Illustrations of the use of the Microscope in Clinical Medicine*."

CHAPTER IV.

THE ANATOMY OF THE KIDNEY—ITS ACTION IN HEALTH AND DISEASE—*Cortical and Medullary Portions of the Kidney —Pelvis—Mamillæ—Infundibula and Calyces—Artery— Vein—Nerves—Lymphatics—Secreting Apparatus—The Uriniferous Tube—Of the Circulation in the Kidney— Epithelium—Of the Basement Membrane of the Tubes and of the so-called Matrix—On some Points connected with the Physiology of the Kidney—On the formation of Casts of the Uriniferous Tubes—Of the Cast—Circumstances under which the Renal Secretion may be altered in Quantity or Quality—On the Absorption of Substances from the Stomach, and their excretion in the Urine—Morbid Changes affecting the Structure of the Kidney—Of Bright's Disease—Dr. Johnson's Investigations.*

IT is clearly impossible to discuss with advantage the characters of the urine in health and disease, or the formation of urinary calculi, without studying the anatomy and action of the kidney. As these organs are essentially concerned in the removal from the organism of soluble substances resulting from disintegration, the accumulation of which in the blood would most seriously impair the action of many important organs, they are worthy of special study on the part of every physician. It is not too much to say that, without a good knowledge of the anatomy and physiology of the kidney, it is impossible for the practitioner to understand the nature of a very large and important class of diseases, and it is certain that cases of one or other form of renal disease will very frequently come under the notice of all engaged in practice in large cities. Nor are kidney diseases exclusively confined to the inhabitants of cities. Moreover, there are no diseases in which the

practitioner can be of more real service to the patient, and none which it is more important to recognise at once. The treatment of many of these morbid conditions has been satisfactorily determined, and there is no department of medicine in which the knowledge we possess is more definite and accurate, or in which the practical utility of our knowledge is more manifest. A thorough acquaintance with the physiological changes occurring in the kidney will alone enable us, to the greatest advantage of our patients, to suggest and apply remedies in various cases of disease. For these reasons, therefore, I consider it right to describe briefly the anatomy and action of the kidney before considering the characters of the urine.

I shall describe the anatomy as simply as I can, and in order to spare words I have made several drawings to illustrate the structure and arrangement of the various tissues entering into the formation of the renal apparatus. The subject is so extensive that I cannot hope to do more than offer some very brief remarks; and I shall omit discussing many points connected with the pathology which would be necessary to give my account any pretensions to completeness.

89. General Anatomy.—The general anatomy of the kidney is shown in section in the diagram (Fig. 39, Plate VIII.). Each kidney is enclosed in a capsule composed of fibrous tissue, but abundantly supplied with blood-vessels, and with lymphatics. At the hilus or notch, the capsule is continuous with the areolar tissue which surrounds the large vessels, and extends in intimate relation with them for a certain distance into the interior of the organ. Fig. 39, Plate VIII. shows the general structure of the kidney as seen upon section. The *ureter* traced upwards is continuous with the pelvis of the kidney. From the *pelvis*, narrow funnel-shaped prolongations *(infundibula)* are observed. These extend to the *pyramids*, being reflected around the apex of each to form a cup-shaped depression *(calyx)*. The apices of some pyramids are also seen opening into the infundibula towards the observer. The *cortex* extending round the kidney and passing inwards between the pyramids, is easily distinguished from the *medullary portion*, by the irregular granular appearance it presents to the unaided eye, and by the numerous minute points *(Malpighian bodies)* seen in it. The medullary

portion is composed of the pyramids, which consist of tubes which are nearly straight, and converge to the apex or *mamilla*, where they open by about fifteen or twenty orifices. Portions of arteries and veins are observed between the infundibula, and smaller vessels are seen in the section between the cortex and medulla. These give branches in two directions, *outwards* to the cortex, and *inwards* to the pyramids. The drawing is about two-thirds of the natural size. The scale at the side is divided into eight spaces, representing half-inches.

90. Cortex.—The *cortex* or *cortical portion* of the kidney consists of a layer about half an inch in thickness, forming the surface of the entire organ, and dipping down often to the depth of an inch between the pyramids.

91. Medullary Portion.—This lies immediately within the cortex, and is directly continuous with its inner surface. It is composed of from ten to fifteen pyramids, their bases being continuous with the cortex; their apices free, and projecting into the cavity in the interior of the organ *(pelvis of the kidney)*.

92. Pelvis: Mamillæ: Infundibula: Calyces.—The mucous membrane, with the fibrous and muscular tissue externally, forms a dilated cavity in the interior, called the pelvis (*c*, Fig. 40). From the pelvis, passing towards the apices of the pyramids, are several tubular prolongations, forming funnel-shaped channels (infundibula), *e*, *d*, usually not more than twelve in number. In many cases, two pyramids open into one infundibulum. Each of these funnel-shaped prolongations forms a cup-like cavity round the tip of the pyramid (*mamilla* or *papilla*), called a *calyx*, *f*. Lastly, the mucous membrane, after forming this reduplication, is firmly adherent to the mamillæ, and immediately continuous with that lining the tubes, which open by orifices varying from ten to twenty or more in number, upon the summit (*h*, Fig. 40, Plate VIII.). Some of the free extremities of the pyramids are thin, and extend in a longitudinal direction, perhaps for the distance of a quarter of an inch or more. The term mamilla or papilla can hardly be properly applied to these.

The pelvis is dilated at the notch or hilus, where it leaves the kidney, and soon contracts to a tube with muscular parietes (ureter),

which opens into the bladder—one on each side of this viscus, at its posterior aspect. Fig. 40, Plate VIII., represents a thin section of a portion of the kidney. *a*, cortical; *b*, medullary portion; *c*, pelvis; *d*, infundibulum; *e*, opening of an infundibulum into pelvis; *f*, calyx; *g*, pyramid; *h*, mamilla or papilla; *i*, adipose tissue; *k*, large veins divided in making the section. Small arteries are also seen cut across in different parts of the section, some large branches being situated between the cortex and medullary portion of the organ.

93. Artery.—Outside the mucous membrane of the pelvis of the kidney, the artery, entering at the hilus behind the vein, divides into branches, which are distributed to the organ. The branches of the artery do not anastomose, but radiate outwards as they divide and pass towards the cortex. Arrived at a point between the cortical and medullary portions of the kidney, many branches pursue for some distance a more or less horizontal, or rather curved course, corresponding to the bases of the pyramids. From these, radiating outwards in the cortex, pass a number of nearly straight branches, which give off on all sides little vessels which terminate in Malpighian bodies. The great bulk of the blood carried by the artery to the kidney is distributed to Malpighian bodies; but a few small arterial branches pass straight through the cortex, and supply the capsule; others are distributed upon the external surface of the pelvis, and ramify amongst the adipose tissue in the neighbourhood; while some (*vasa recta*) are given off from the vessels that lie between the cortex and medulla, many branches of which I have shown, anastomose with each other, and pass in the substance of the pyramids towards their apices.

94. The Emulgent or Renal Vein is formed by the union of a number of smaller trunks which receive the blood from the capillaries. Numerous large branches may be seen in the intervals between the cortex and medulla (Fig. 40, *k*). They converge from all points, receiving the blood distributed by the artery as above described, and at length form one large trunk, which emerges at the hilus at its anterior part, and opens into the inferior cava.

95. Nerves.—The nerves are branches of the sympathetic, and are distributed upon the coats of the artery. They may be traced for a considerable distance into the interior of the gland, always

accompanying the subdivisions of the artery. I have seen branches on the Malpighian arteries, but have not been able to ascertain how they terminate. It is possible that small branches may pass into the Malpighian tuft. I have seen numerous very fine branches of nerve fibres passing between the uriniferous tubes of the frog's kidney. The kidney of the frog receives many branches of nerve fibres, besides those which pass into it with the artery. In the human subject all the arteries and the vasa recta are freely supplied with nerve-fibres and numerous very fine fibres, with nuclei connected with them ("connective tissue corpuscles" of authors), lie around the tubes.

96. Lymphatics.—There are numerous lymphatic vessels distributed to the kidney. They leave the organ at the hilus, where the large vessels enter. I have not succeeded in injecting these lymphatics as I have in the case of the liver, where they exist in great number, and are found both in the substance of the capsule and in the portal canals. The capsule of the kidney is, probably, also supplied with lymphatics, although it is not easy to demonstrate them by injection.

97. Secreting Apparatus: Uriniferous Tubes.—The secreting apparatus consists of tubes lined with epithelium. The tube commences in a small flask-like dilatation, which embraces the capillary vessels of the Malpighian tuft (Fig. 41, Plate VIII.). In continuation with this is the tube which, in the greater part of its extent, is very much convoluted, being frequently bent upon itself; so that a great length of secreting tube is packed in a very small space. The convoluted tubes are so close together, that it is impossible to trace, in man and mammalian animals generally, the course of one individual tube for any great distance; and, in thin sections of the cortex, segments of the windings of different tubes are seen divided in all directions.

The tubes, as they are about to leave the cortex, pursue an almost straight course, and here commences the ductal portion of the urinary apparatus. A certain number of these straight tubes extend nearly to the surface of the kidney, and carry off the secretion from the tubes which lie most superficially. These may be seen lying in the cortex, at certain intervals. In the pyramids, the tubes are straight; and as they converge, they unite together, and become fewer in number; while their calibre greatly increases as they pass towards the apex

Fig. 39.

§ 89.

Fig. 40.

§ 92.

Fig. 41.

§ 97.

× about 50

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of the pyramid, where they open as before described. Some of these orifices are figured in Plate XXII., Fig. 5, Vol. i., "*Archives of Medicine*, 1859."

98. Summary of Structure.—The *cortex* of the kidney, then, is composed of Malpighian bodies, the flask-like dilatations and convoluted portion of the uriniferous tubes, with capillaries, the arrangement of which will be presently considered, branches of arteries and veins, with a certain amount of transparent and fibrous tissue.

The *medullary portion* is composed of the pyramids, which are formed of the straight portion of the uriniferous tubes with capillaries, bundles of small straight branches (vasa recta) from the arteries, and numerous straight branches of small veins; the majority of these nearly straight vessels, however, consists of vessels resulting from the division of the efferent vessels of the Malpighian bodies situated nearest the pyramids (Plate IX., Fig. 42). There is also an intervening material containing nuclei, and having a very firm consistence, but not a distinctly fibrous network or stroma.

99. Circulation in the Kidney.—The course of the blood, as it circulates in the vessels of the kidney, may now be described. Starting from the arterial branches between the cortex and medullary portion of the organ, the blood pursues two directions—*outwards* towards the external surface, and *inwards* towards the apices of the pyramids.

Of the blood which passes *outwards*, a little is distributed to the capsule and membrane of the pelvis, but by far the larger proportion is carried to the Malpighian bodies. Arrived at the Malpighian body, the trunk of the little artery divides into three or four dilated branches, each being as wide as the artery itself. These subdivide into capillary loops which have their convexity towards the uriniferous tube, and which lie uncovered by epithelium within its dilated commencement; so that fluids passing through the membranous walls of these capillaries, and, indeed, everything escaping from them when they are ruptured, must at once pass into the uriniferous tube. The blood is collected from the capillaries by small venous radicles which lie in the central part of the tuft, which there unite to form a single efferent vessel that emerges usually at a point very close to that by which the artery entered. In some specimens, I have seen two and even three efferent vessels, but this is not common.

The arrangement of the secreting structure and vessels of the kidney of man, magnified about 50 diameters, is represented in the drawing, Plate VIII., Fig. 41; *a*, Malpighian body; *b*, Malpighian artery or afferent vessel; *c*, efferent vessel; *d*, capillary network, into which the blood passes from the efferent vessel; *e*, small venous radicle, which carries off the blood after it has traversed the capillaries just alluded to; *f*, commencement of the uriniferous tube by a dilated extremity, which embraces the vessels of the tuft; *g*, the tube; near the point where it opens, it joins others, *h*, to pursue a straight course towards the pyramids of the kidney; *i*, another tuft, the vessels of which are empty and shrunken; *k*, portion of a tube cut across, showing the basement-membrane. The attention of the reader is particularly directed to this figure.

The *efferent* vessel of the tuft pursues a short course, and then divides into an extensive network of capillaries, in the meshes of which the tubes ramify. It is from the blood, which, after passing through one system of capillaries in the tuft, thereby losing much of its wàter, slowly wanders in a more concentrated state, through this extensive capillary system, that the solid constituents of the urine are separated by the agency of the epithelial cells lining the tubes. The water, *fully charged with oxygen*, transuding from the capillaries of the Malpighian body, is made to traverse in succession the epithelial cells lining the tube. At the same time that it dissolves the different substances which have been separated from the blood, it *oxidises* the matter forming the outer part of the cells, and converts it into soluble substances. The blood becomes richer and richer in solid constituents as it approaches the straight portion of the tube. From the intertubular network of capillaries above alluded to, the blood is collected by small venous radicles, which at last pour their contents into the renal or emulgent vein.

100. Vasa recta.—Of the comparatively small quantity of the blood which passes *inwards* towards the apex of the pyramids, a very small portion passes into vessels which supply the walls of the pelvis and adipose tissue. The remainder is conducted towards the apex of the pyramid by the *vasa recta*, or branches resulting from the division of small trunks of the *artery*, one of which is represented at *a*, Plate IX., Fig. 42. These *vasa recta* terminate in a capillary network, in the longitudinal meshes of which the straight portion

of the tubes lies. It must not be concluded, however, that all the straight vessels in the pyramids are vasa recta, with the structure of arteries; for the efferent vessels of those tufts near the pyramids divide into long and nearly straight branches, which pour their blood into this system of capillaries, from which it is collected by radicles which also pursue a straight course, and unite together to form small trunks, which open into branches of the vein lying between the cortical and medullary portions of the kidney. This arrangement was fully described by Bowman in his memoir. He thought that *all* the straight vessels came from the Malpighian bodies. Virchow seems to consider that all, or very nearly all, the straight vessels consist of vasa recta; but I have shown by *transparent injections* that many of these vessels are the efferent vessels from Malpighian bodies, as Bowman long ago stated, while a certain number undoubtedly come directly from arteries (Plate IX., Fig. 42). The latter have the structure of arteries, and are freely supplied with nerve fibres. In diseases, in which much more blood is made to pass into the pyramids than normally, the coats of these arterial branches become much thickened, and the circular fibres are more readily demonstrated than in health. ("On the Vasa Recta in the Pyramids of the Kidney," *Archives of Medicine*, No. IV., 1859.)

It should be mentioned, that the intertubular capillaries are everywhere continuous; and from this network venous radicles arise at certain intervals. The arrangement of the capillaries is well shown in the frontispiece of the "*Illustrations of Urine, Urinary Deposits, and Calculi.*"

101. Epithelium.—The epithelium of the kidney differs in different parts of the tube. That in the convoluted portion of the tube is described as being polygonal; it projects into the tube to the extent of one-third of its calibre. That in the straight portion of the tube is flatter, and approaches to the scaly variety of epithelium. Although the convoluted portion of the tube is much wider than the straight portion, *the diameter of the channel is much wider in the latter position than in the former*, owing to the much greater thickness of the epithelium in the secreting portion of the tube. Epithelium from the convoluted portion of the uriniferous tube is represented in Plate IX., Fig. 44; *a*, treated with acetic acid. × 215.

In healthy human kidneys, I have never seen the outline of the

cells so distinctly as figured in various works, or in the upper part of my own figure. The round body, usually termed the nucleus, is very clear and well defined, and this seems to be surrounded by a quantity of soft granular matter. I think it very doubtful if there is a cell wall external to this. In many cases of disease, the round central body is all that can be made out; and sometimes these are found in great number in the urine. The round 'cells' present in the urine, in cases of acute nephritis, are generally the nuclei of the 'cells' lining the uriniferous tube, the soft granular material around having been completely disintegrated. By the action of acetic acid, nucleoli may be observed. It would seem as if the granular matter external to the rounded granular body (nucleus) was altered in character under certain circumstances. From numerous observations, I feel compelled to dissent from the descriptions generally given both of the kidney and liver epithelium, inasmuch as the appearance of a cell-wall can only be seen under certain circumstances; and in many animals there is undoubtedly no such structure. I would rather say that the so-called nuclei are embedded in a granular material, by which they are separated from each other by nearly equal distances, as represented in the lower part of Fig. 44, Plate IX. If, instead of using the terms *nucleus*, *cell-wall*, and *cell contents*, we consider the central mass as germinal or living matter, which is coloured by carmine, and the outer granular matter as "formed material," the changes actually observed can be described without any difficulty or confusion. The formed material is rendered transparent by acetic acid, as represented at *a*, Fig. 42, and during life it is slowly converted into soluble substances by the action of the oxygen dissolved in the water discharged from the Malpighian capillaries.

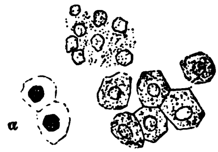
The epithelium in the straight portion of the tube is much flatter than that in the convoluted part, and probably serves the office of a protective covering. It is doubtful if it takes part in secretion. The epithelium from the pelvis of the kidney is represented in Plate IX., Fig. 45, and that from the ureter in Fig. 46.

102. Matrix and Basement-Membrane of the Tubes.—The basement-membrane is easily demonstrated by washing a thin section of the kidney, so as to remove the epithelium. It is much stronger and thicker in the pyramids than in the cortex (Plate IX., Fig. 43*b*).

Fig. 42.

§ § 98, 100

Fig. 44.



§ 101 × 215

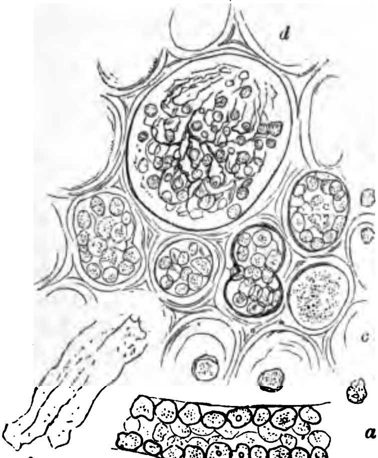
Fig. 45.

§ 101

Fig. 46.

§ 101 × 215

Fig. 43.

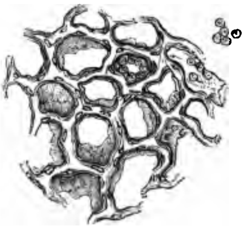


§ 102 × 215

Fig. 47.

§ 102. × 100

Fig. 48.



§ 102 × 100

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The so-called matrix described and delineated by Goodsir, Kölliker, Dr. G. Johnson, and others, I have not succeeded in demonstrating to my satisfaction; for, when the capillaries of the kidney have been distended with transparent injection, I have failed to demonstrate any fibrous structure at all resembling the drawings given of it, between the wall of the tube and that of the vessels. The appearance considered to be fibrous matrix is easily seen in any thin section of an uninjected kidney which has been washed and examined in water; but in such a section it is imposible to distinguish the walls of the tubes, those of the capillaries, and the so-called fibrous matrix, from each other. It has been figured by many as a distinct structure; and Plate IX., Fig. 47, representing a section which has been washed in water, gives the appearance most distinctly. The capillaries are not injected, and, being collapsed and shrunken, exhibit the fibrous appearance which is considered to depend upon the matrix. Fig. 48 represents an injected specimen from the same kidney, which does not exhibit any indication of fibrous tissue existing between the vessels and the tubes. The nuclei in the coats of the vessels, and some nuclei external to them which are probably connected with nerve fibres, are distinctly seen, but no fibrous matrix is observable. Here and elsewhere, as I have shown, the stretched and crumpled capillaries produce an appearance resembling fibrous tissue or matrix of the kidney ("*Archives of Medicine*," No. III., 1858). A thin section of the cortical portion of a kidney, which had been slightly washed in water, is also represented in Plate IX., Fig. 43. The vessels are not injected. *a*, convoluted portion of uriniferous tube; *b*, a portion of a tube stripped of its epithelium; *c*, outline of tube and crumpled capillaries, having a fibrous appearance—the so-called matrix; *d*, very small Malpighian body. Loops of vessels shrunken, showing cells in their walls. × 215.

This so-called matrix has been compared to the ultimate ramifications of Glisson's capsule; and it has been considered necessary as a support to the structures of which the gland is composed. I have never seen fibrous tissue in the situation described in health in either gland; and it is quite obvious that the structures do not require any supporting tissue, as they mutually support each other; and any matrix would tend to increase the distance between the secreting cells and the blood; while we certainly find in these organs every arrangement to reduce this as far as possible consistently with

strength. If this matrix exists, it ought to be developed as a structure distinct from the tubes and vessels; but it has not been demonstrated at an early stage of development of the kidney or liver by anyone. In a careful examination of embryonic structures generally, one cannot fail to be struck with the absence of such fibrous or connective tissue, which is by some regarded as an essential part of every organ. It is at this early period that the tissues are softest, and seem most in need of support; and yet the embryonic structures are peculiarly destitute of any supporting fibrous framework whatever. The morbid changes are explained as well by supposing the formation of a new material between the walls of the tubes and those of the vessels, or by a thickening or other change in one or both of these structures, as by attributing them to an alteration in the matrix or intertubular areolar or fibrous tissue (*Bindegewebe*).

The conclusions to which I have arrived, from numerous investigations on this subject, may be summed up as follows:—

1. In the cortical portion of the kidney there is no evidence of the existence of a "*fibro-cellular matrix.*"

2. The fibrous appearance observed in thin sections of the kidney which have been immersed in water is due to a crumpled, creased, and collapsed state of the membranous walls of the secreting tubes and capillary vessels.

3. A small quantity of a transparent and faintly granular material, with distinct nuclei, the nature of which has not yet been conclusively determined, is alone to be demonstrated between the walls of the tubes and the capillary vessels.

4. The changes met with in disease can be fully explained without supposing the existence of a *fibrous matrix*.

103. On some Points connected with the Physiology of the Kidney.—The course of the blood has been fully described, and it has been shown how eminently adapted the Malpighian tuft is to facilitate the free escape of the watery parts of the blood. The influence of the nervous system upon the secretion of urine is well known. Nerves may be traced upon the large arteries, and followed on the small vessels for a considerable distance. I have seen nerves upon the Malpighian arteries which may be traced up to the tuft. I have not succeeded in demonstrating nerves in connexion with the capillaries of the tuft; but a careful examination of several specimens

has led me to conclude that these capillaries are supplied with nerves, as is also the case with the capillaries of the ciliary processes of the eye, and some other capillary vessels. In many cases, the so-called "connective-tissue corpuscles" external to capillary vessels, belong to exceedingly fine nerve fibres, which are only to be demonstrated with the utmost difficulty. I am now investigating the mode of distribution of the nerves to vascular structures, and I hope soon to be able to express myself more positively on these very interesting questions.

The appearance of some of the capillary vessels of the Malpighian tuft of the human kidney, separated and, to some extent, flattened out, is represented in Plate X., Fig. 49. The vessels were injected with dilute Prussian blue injection. The nuclei connected with their walls are well seen: *a*, a few coils separated from the rest of the tuft; *b*, part of a loop somewhat compressed, showing the nuclei a little flattened; *c*, tissue connecting the coils with each other, in consequence of which the globular form of the tuft is preserved, even when it is removed; *d*, a small portion of a capillary compressed as much as possible, showing the thickness of the capillary wall at the point of reduplication.

Collateral Circulation.—Virchow lays considerable stress on the existence of a collateral circulation through the vasa recta. He considers that the circulation in the medullary portion of the kidney is more free than it is in the cortex, because the blood in the latter region does not pass through Malpighian bodies. There can be no doubt of the correctness of Virchow's views upon this question, and I can confirm many of his statements from personal observation. Some years ago, in examining some specimens of diseased kidney, I was much struck with the thickness of the walls of some of the vasa recta in the pyramids. Upon further examination, these were found to exhibit the circular muscular fibres so characteristic of arterial walls. I have since carried out further investigations upon the healthy kidney, and have proved that many of the straight vessels running parallel with the tubes in the pyramids of the kidney are in reality small arterial branches with muscular walls. I suspect that some of these branches communicate very readily with the veins in the same situation; and it is not impossible that, in health, the blood may be caused to pass through the Malpighian bodies, or may be diverted, and, by passing through the vasa recta, be returned to

the veins more rapidly. This subject is one of very great interest, in connexion with the renal circulation.

In a state of health, the diminished rapidity of the circulation in the capillaries of the Malpighian body, consequent upon the greatly increased area of the capillaries, which the blood must traverse as it flows from the small artery, which alone supplies them, favours the transudation of water through the capillary walls. This fluid must at once pass into the uriniferous tube; and as it gradually traverses in succession the cells which line it, the soluble substances are dissolved out—the quantity of solid constituents gradually increasing as the solution passes down the tube, while the substances are being more fully oxidized at the same time. Now the blood just brought from the Malpighian body has parted with water, and, being more concentrated, is richer in *urinary constituents* than the blood in any other part of the kidney. This is conducted by the vessels into which the efferent vessel of the Malpighian body divides, to the upper part of a uriniferous tube below the Malpighian body. We should expect that the cells in this region would be more fully charged with soluble urinary constituents than those lower down the tube; and, in accordance with this view, we find that these cells are acted upon by the almost *pure water* which has just escaped from the capillaries of the Malpighian bodies; while, by the time the fluid has reached the cells at a lower point of the tube, it is already charged to a great extent with soluble constituents, and its solvent power is, of course, proportionately diminished.

Not the least important office of the cells lining the convoluted portion of the uriniferous tube is undoubtedly that of separating from the blood a considerable quantity of the *débris* of blood-corpuscles, in the form of *extractive matters*. It is almost certain that the cells have the power of altering some of the substances they separate from the blood, and converting them into these peculiar urine extractives, the physiological importance of which must be very great, as so large an amount is excreted.

Some observers have considered that special vessels are concerned in carrying blood to *nourish* the tissues of the gland, and Dr. Goodfellow thinks that the intertubular capillaries are concerned in this office. The quantity of blood passing into these vessels is, however, far greater than is required for the nutrition of the tissues of the kidney, and reasons have been already advanced for accepting the

view propounded by Bowman with reference to these capillary vessels. The tissues of organs generally, are nourished by the plasma present, and do not require special vessels. Many arguments may be adduced against the view, that the hepatic artery merely serves the purpose of distributing blood to nourish the tissues of the liver, as is generally supposed.

The views of Bowman, with regard to the office of the Malpighian body and the epithelium of the uriniferous tube, have been opposed by Ludwig, and more recently by Dr. Isaacs, in America, who tried to prove that the solid constituents were separated by an epithelium, covering the capillaries of the Malpighian body (which, if it exists, is certainly very unlike glandular epithelium generally, and the cells must be very much smaller than he has represented); while, strange to say, he does not attempt to show what office is performed by that enormous extent of epithelial surface in the convoluted portion of the tube, or why the very peculiar relation between the extensive system of capillaries around the tubes and that of the Malpighian body exists. Dr. Goodfellow thinks that the urinary constituents are separated with water from the Malpighian capillaries, and that any constituents of the serum, or blood, that may have transuded through their walls, "are absorbed by the epithetical cells of the tubules or by some other agents."* There does not seem to be any positive evidence that any constituents of the serum do really transude through the Malpighian capillaries. The epithelium is not of the character of that we find usually concerned in absorption; and other objections might be urged against this view, especially certain facts observed in connection with the uriniferous or corresponding organs of some of the lower animals. It seems to me, that Bowman's views on the physiology of the kidney are supported by so many different arguments, that they will be accepted by all who have carefully studied the subject, from the different points of view which he has indicated. Many absolutely new facts must be discovered before the conclusions which he arrived at can be rejected.

104. On the Formation of Casts of the Uriniferous Tubes.—Such, then, being the actions of the kidney in health, we may now consider briefly how these changes may be modified in certain cases. If the arterial walls were relaxed, more blood would pass into the

* "*Lectures on Diseases of the Kidney*," p. 152.

Malpighian capillaries in a given time, and a great transudation of water would take place. If, on the other hand, the arteries became contracted, the secretion of urine would be diminished accordingly. Many sudden and temporary alterations in the circulation of the blood through the Malpighian bodies of the kidney undoubtedly depend upon an influence exerted through the nerves alone; but certain changes which are, unfortunately, of a more permanent character, are due to an altered action of the secreting cells. The rapidity of the circulation in the Malpighian body will be greatly influenced by the rate at which the blood traverses the capillaries around the uriniferous tubes; the flow of blood in these vessels being governed by the attractive force exerted by the cells within the tubes for the urinary constituents dissolved in the concentrated blood. Now if, from any cause, the action of the secreting cells became impaired, and they ceased for a time to exert their attraction for the constituents they ought to separate from the venous blood, a retardation to the circulation in these capillaries would result. This would affect backwards, as it were, the capillaries of the Malpighian tuft, in which the blood, urged on through the arteries, would tend to accumulate. Their thin walls, being much stretched, would not resist the passage of certain constituents of the blood; albumen and extractive matters would pass into the tube, and escape in the urine. Supposing this state of things to go on, the pressure on the Malpighian capillaries must necessarily increase; and these capillaries, distended to their utmost, and their walls stretched to the last degree, would at length burst, and all the constituents of the blood, including the blood-corpuscles, would pass into the tube, and would escape with the urine. The tenuity of the walls of the Malpighian capillaries, which permits the escape of water in health, will favour the escape of other constituents of the blood, and increase the chance of their rupture in disease, if they be exposed to increased pressure; but the collateral circulation already referred to in some measure counteracts such a tendency.

Professor Virchow has lately arrived at the conclusion that albumen and other constituents of the blood more frequently escape from the straight vessels of the pyramids than from those of the Malpighian bodies. According to this view, the constituents of the blood would have to pass through the walls of the tubes, as well as through those of the capillaries, in which case we

ought to find an œdematous condition of the kidney, and blood effused between the tubes more frequently than is the case. It seems to me that, before such a lesion was possible, the Malpighian capillaries must have become much thickened and altered in structure. In many chronic cases, as has been shown by Dr. Johnson, the Malpighian arteries become enormously thickened; and I have often observed the capillaries of the Malpighian body in a like condition; so that the permeability of their walls must be very greatly diminished. There can be no question that in many cases the blood-corpuscles and fluid matters escape from the Malpighian capillaries, for they may be seen in the convoluted portion of the tubes after death, and I have seen bodies extravasated from the vessels even in the capsule of the Malpighian body.

105. Casts.—In many cases of congestion, and in inflammation of the kidney, a spontaneously coagulable material is effused into the tubes, and coagulates there, forming a *cast or mould of the tube*, which is gradually washed out by the fluid which is secreted behind it, and thus it finds its way into the urine, from which it may be easily separated for examination.

A cast is composed of a coagulable material which is effused into the uriniferous tube; and, becoming solid there, it entangles in its meshes any structures which may be in that part of the tube at the time, and forms a mould of the uriniferous tube. The characters vary very much in different cases, according to the state of the tubes and the part in which the effusion of the matter takes place. Various substances are often entangled in the cast; and, by observing the character of these, we are often enabled to ascertain the nature of morbid changes going on in tubes at the time the cast was being formed. Great difference of opinion has been expressed with reference to the nature of the material of which the cast is composed. By some it has been termed fibrine; but the striated appearance always present in coagula of this substance is not found in the cast. Others have considered the cast was composed of albumen; but it is not rendered opaque by means of those reagents which produce precipitates in albuminous solutions. Not more than five years since, it was stated by two observers in France and Germany of high reputation, at least in other branches of scientific inquiry, that the cast really consisted of the basement membrane of

the uriniferous tube. How such a statement could be made by any one possessing even a slight knowledge of the anatomy of tissues, it is difficult to conceive.

The transparent material probably consists of a peculiar modification of an albuminous matter possessing somewhat the same characters as the walls of some epithelial cells, the elastic laminæ of the cornea, the walls of hydatid cysts, etc., but not condensed like these structures. I think it not improbable that these casts of the uriniferous tubes may really be composed of the material which, in health, forms the substance of epithelial cells. In disease, this substance, perhaps somewhat altered, or not perfectly formed, collects in the uriniferous tubes, and coagulates there. This receives some support from the fact that occasionally casts are formed although no albumen passes into the urine. According to this notion, it is possible that a cast might be formed quite independently of any congestion or morbid condition of the Malpighian tuft; but, as a general rule, there can be no doubt that serum escapes and albumen is found in the urine.

The diameter and general character of the cast will be determined by the state of the uriniferous tube at the time of its formation, as the researches of Dr. Johnson have indisputably proved. If the epithelium be abnormally adherent, the cast will be very narrow; if, on the other hand, the epithelium be removed, it will be of the width of the tube. Should the epithelium be disintegrating, the cast will afford evidence of the change. If in a state of fatty degeneration, fat-cells will be entangled in it. In hæmorrhage from any part of the secreting structure, blood-corpuscles are present; and, when suppuration occurs, the cast contains pus-corpuscles. When the transudation of the coagulable material occurs in a tube to which the epithelium is intimately adherent, or in a tube whose walls are smooth, the cast will be clear and perfectly transparent. The import of all these different characters is fully discussed in the works of Dr. Johnson; and several interesting cases, under observation for a considerable period of time, will be found reported in Dr. Basham's work.

The different forms of casts which are most frequently met with will be considered under the head of urinary deposits.

Professor Virchow thinks that casts are very constantly, if not entirely, formed in the straight portion of the uriniferous tubes; but

many of the facts already referred to strongly militate against this idea, and it is common enough to see the casts in the tubes of the cortex. Moreover, as I have demonstrated in several cases, the cast receives successive layers upon its outer surface, as it passes down the tube ("*Illustrations*," Plates XIV. and XVI.). There is no doubt that casts are found in the *straight* as well as in the *convoluted* portion of the uriniferous tubes, but the value of the characters of the cast found in the former situation with regard to diagnosis cannot be questioned, while it is obvious that from casts found in the straight portion of the tubes we can learn nothing as to the nature of morbid changes occurring in the secreting part of the gland. In Plate X., Fig. 50, portions of casts from the convoluted portion of the tubes are seen embedded in transparent material. The drawing was taken from specimens found in the urine of a case of acute suppurative nephritis. It is probable that the small casts were found in the convoluted portion of the uriniferous tubes, and that the transparent material in which they were embedded, coagulated in the straight portion of the tube, near its opening, at the summit of a papilla. We may, therefore, conclude that casts are generally formed in the convoluted portion of the tube, although, in certain cases, the coagulable matter may be effused in the straight portion also, in which case the diameter of the cast will be very much greater than if it was formed entirely in the convoluted part of the uriniferous tube. In certain cases in which there is evidence of considerable irritation in the kidneys, sometimes so much as to lead one to suspect the existence of calculus in the kidney, a number of flocculent shreds may be passed in the urine. I have seen several cases in which these were composed of a very transparent and slightly granular material like ordinary mucus. In Fig. 83, Plate XVII., is represented such a cast which must have been entirely formed in the straight portion of the tubes. The ramifications from the larger mass extended into the fine tubes which open into the larger ones in considerable number. The drawing (× 75) was taken from specimens found in the urine of a patient under the care of my friend, Mr. Charles Hawkins, who had been suffering from renal irritation and affection of the bladder for many years.

106. Circumstances under which the Urine may be altered in Quantity or Quality.—In the remarks I am about to make, I

shall consider it as proved that the solid constituents of the urine are separated by the cells lining the uriniferous tubes, while the water filters through the walls of the capillaries of the Malpighian body. Diuretics may act in two ways—1. By causing increased transudation of fluid from the Malpighian tuft, in which case pale urine, containing very little solid matter, will escape in considerable quantity; 2. By causing the cells to separate from the blood, a larger amount of solid material, in which case a highly concentrated urine, rich in solid matter, will be secreted in greater proportion than in health. In certain diseases, there seems to be a tendency on the part of the kidneys to throw off morbid material which exists in the blood. If, under these circumstances, the flow of blood to the kidneys is not compensated for by rapid removal of these matters, congestion, perhaps running on to inflammation, occurs, and there is danger of serious damage to the organ.

It is in this manner that the albuminuria following scarlatina, and that coming on from exposure to cold, are to be explained. This subject has received full consideration from Dr. Johnson, in his work "*On Diseases of the Kidney*," and also in that "*On Cholera*." The action of many irritating diuretics is to be explained in a similar manner. A quantity of cantharides, which would do no harm to a strong healthy man with sound kidneys, would produce dangerous congestion and inflammation, with rupture of the capillaries of the Malpighian body, in a person who was recovering from an illness, or in one whose kidneys were affected by disease. In the one case, the secreting power of the cells appears increased by the action of the drug; while in the other they are incapable of effecting the increased amount of work suddenly thrown upon them, and the results above described must occur. Kramer and Golding Bird state that squill, capaiba, broom, juniper, and guiacum, cause the removal of an increased proportion of water from the blood, but do not influence the quantity of solid matter removed from the body in twenty-four hours. It seems probable that these remedies affect the capillaries of the Malpighian tuft, either directly, or perhaps more probably, through their action upon the nerves distributed to the renal vessels.

In cases where the blood is very watery, the excess of fluid is carried off by the kidneys; but at the same time, a greater amount of solid matter is removed in a given time, partly arising from the tissues being washed out by the large quantity of fluid, and partly

because the formation of urea, &c., is favoured by a dilute state of the fluids.

Many neutral salts (nitrates, sulphates, &c.) seem to increase the secretion of urine by being attracted from the blood in a state of solution, in all probability by the renal epithelium, the kidney being the channel by which they naturally leave the system. Urea has a similar diuretic action. Within certain limits, the greater the quantity of these substances in the blood, the more will be removed by the renal epithelium, supposing this to be healthy. The more strongly the epithelial cells be charged with urinary constituents, the greater the quantity of water required to dissolve them out. This seems to be effected as follows:—When the urinary constituents are not removed from the cells by the water coming down from the tuft as fast as they are separated from the blood, they must accumulate until the surcharged cell ceases to exert that attractive force upon the blood in the capillaries around the tube which it does ordinarily. The tendency to stasis in the circulation thus caused necessarily interferes with the free passage of the blood through the Malpighian capillaries, and the increased pressure which results causes the escape of fluid into the tube, which washes out the solid matter accumulated in the cells. The latter resume their action, the circulation becomes free again, and the normal relation between the action of the cells of the tube and the Malpighian body is re-established.

Now alkalies, and especially the citrates, tartrates, and acetates, which become converted into carbonates in the system, increase not only the quantity of water removed from the system, but also materially augment the proportion of solid matter. These salts increase the quantity of urea and other matters formed. They seem to favour the conversion of the products resulting from the disintegration of tissue into these constituents. The action of such remedies is very desirable in a vast number of cases; and even where the kidneys are diseased, these salts act favourably.

A certain degree of dilution is necessary to ensure the diuretic action of many neutral salts. If the density of the solution be very great, exosmose of fluid from the blood will take place, and a purgative action will be produced. Certain salts may be made to act as purgatives or diuretics, according as they are diluted with a small or with a large quantity of water. The observations of Dr. Headland,

however, show that this physical explanation cannot be applied in all cases. That sulphate of magnesia is absorbed into the blood, at least in the majority of instances, there can be no doubt. It is often excreted in large quantity in the urine; and it is probable, as Dr. Headland suggests, that its *purgative action* is due to its removal, in the form of a weak solution, from the blood by the action of the intestinal mucous membrane.

The excretion of urine will also be materially affected by all those circumstances which influence the circulation in the kidney. There exists a compensating action between the cutaneous secretory surface and the kidneys. If a large quantity of water escapes in the form of sweat, the urine will be small in amount and highly concentrated; but if, from the effects of cold, there be scarcely any perspiration, the excess of fluid is entirely removed by the kidneys, and the solids of the urine are therefore held in solution in a much larger quantity of water. Pressure on the renal arteries, or on the aorta above their origin, will diminish the secretion of urine. Pressure on the veins, on the other hand, will first of all cause an increased flow of urine, and afterwards albumen will escape. In congestion of the liver and portal system, the amount of solids is greatly increased. It would appear that, in many cases, where the action of the liver is imperfect, and especially in some forms of organic disease, the kidneys, to some extent, perform the functions of the liver. In jaundice, both colouring matter and biliary acids are carried off in the urine. In this case, however, it must be borne in mind that these biliary constituents are formed by the liver, reabsorbed into the blood, and separated from it, as are many other substances abnormally present, by the kidney. In many affections of the liver, the urine-pigment is much increased; and it is probable that a certain proportion of material which, in a state of health, would have been converted into bile, is transformed into certain extractive matters and other substances, and eliminated in the urine. The crisis of many acute diseases is characterised by the presence of a large quantity of solid matter in the urine, and increased action of the kidney. Free sweating, and the secretion of a urine containing a large amount of urea and urates, in the course of many diseases, are often the earliest and most important indications of approaching convalescence. Dr. Golding Bird showed that abatement in the severity of the symptoms of ague was always associated with an increase in the amount of solid

matter in the urine. Now, in all these cases, it is obvious that the activity of the renal epithelium is increased. The separation of urinary constituents from the blood cannot be regarded as a mere percolation, but is dependent upon a vital property of the cells. It is probable that these cells take part in the actual formation of some of the urinary constituents, just as sebaceous matter is formed by the cells of the sebaceous glands, saliva by those of the salivary glands, &c. An alteration in the proportion of the water is rather to be attributed to temporary alteration in the calibre of the arteries which supply the Malpighian bodies, and to the variable pressure exerted by the blood as it traverses the Malpighian capillaries, depending, to some extent, upon the freedom with which it passes onwards into the capillary system, among the meshes of which the tubes lie.

107. On the Absorption of Substances at the Stomach, and their Excretion in the Urine.—The rapidity with which weak solutions are absorbed from the digestive organs, and secreted by the kidney, is marvellous. In Mr. Erichsen's well known experiments, it was shown that ferrocyanide of potassium could be detected in the urine within a minute after it had entered the empty stomach. These interesting conclusions were derived from experiments made on a case in which, from the deficiency of the anterior wall of the bladder and abdomen, the orifices of the ureters could be seen, and the urine collected as it trickled from them. A German suffering from this terrible malformation was in London in 1858, and many had an opportunity of seeing him, and observing how very soon, after a large quantity of water had been swallowed, the rate of the flow of urine from the ureters increased.

Anything interfering with the absorption of fluid from the stomach or intestinal canal will necessarily affect the secretion of urine. In various cases where the contents of the alimentary canal are in a condition unfavourable for absorption, but a very small quantity of urine is formed. Dr. Barlow has gone so far as to say that the seat of an obstruction in the intestine can be ascertained by noticing the quantity of water excreted in the form of urine. When close to the pylorus, it is stated that scarcely any urine is separated. In ordinary cases of what is known as sick headache, where, from temporary stomach derangement, little absorption occurs for some hours, no urine is secreted perhaps for twelve hours or longer. The

termination of the attack is marked by the very free and rapid action of the kidneys.

108. Morbid Changes affecting the Structure of the Kidney.—In cases where the blood which passes through the kidney is unhealthy, the secreting power of the renal cells is gradually impaired.

In cases of long continued wine and spirit drinking, this change probably results from an altered state of the blood engendered by the spirit, and not from its direct action, for there can be no doubt that large quantities of spirit may exist in the blood without producing any such change; and in all cases in which renal disease results from spirit drinking, the kidneys are by no means the only organs affected. In many instances most of the tissues of the body suffer more or less from a general change which has resulted from alteration in the blood. In advanced cases the cells of renal epithelium lose their healthy appearance, sometimes becoming smaller and condensed, sometimes appearing granular, as if undergoing disintegration. In consequence of the growth of the germs having been interfered with at an early period, the place of the disintegrated cells is not occupied by a new generation.

A complicated series of morbid changes in other structures of the kidney gradually ensues; and, in consequence of the blood being rendered still more depraved by the accumulation in it of matters which ought to be removed by the kidney, other organs suffer, and the changes continue to work on as it were in a circle. The coats of the smaller arteries become much thickened, the capillaries shrink, while their walls become thicker and often granular. The quantity of blood distributed to the organ diminishes; and many of the capillaries, being no longer required, shrink and cease to transmit blood. The diameter of the secreting tubes decreases, while the basement membrane is thickened and becomes more impervious. The whole organ becomes hard, and at the same time small and shrunken. This decrease in size takes place principally at the expense of the cortical or secreting portion of the kidney, as would be supposed. The Malpighian bodies waste. The remains of many may be seen without a capillary in them being pervious; and not a few of those which still exist are found to be so altered that they can hardly be recognised as Malpighian bodies at all. The greater part of the blood sent to the kidney passes into the pyramids by the *vasa recta*,

and soon re-enters the veins, a small quantity being distributed to those tubes and Malpighian bodies nearest the pyramids. The diminished amount of urea, &c., present in the urine, is probably separated in this latter situation; while a certain quantity of water, with a little albumen and the material of which the casts are formed, also escape in this situation, as well as from the straight part of the tubes.

But in such cases the vessels of the kidney are not the only vessels that are altered. The coats of the arteries of the body generally, are more or less altered. The smaller ones lose to a considerable extent their contractile power, and cease to be influenced by changes occurring in the nerves. Persons suffering from chronic renal disease, in an advanced stage, cannot blush. The calibre of the minute arteries is no longer affected by the nerves, and instantly altered by any mental emotion, as in health.

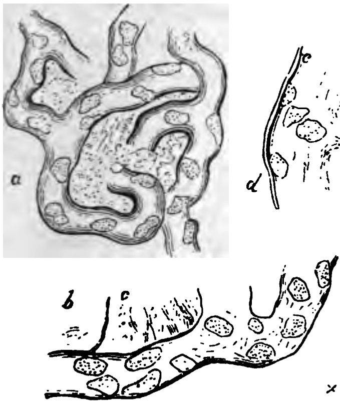
Long before the disease has arrived at this stage, the urine will be found to contain a very small amount of solid matter, which consists principally of salts and extractives, with a very little urea.

By many pathologists these changes are explained by the effusion of inflammatory lymph, and subsequent thickening, condensation, and contraction of the so-called *matrix;* but it seems to me that all the appearances observed may be much more simply accounted for, upon the view that they depend upon depraved nutrition and wasting, than by resorting to the hypothesis of the inflammation of a structure whose existence has not been satisfactorily demonstrated, and which, if it does exist, according to its warmest advocates, only serves as a supporting tissue to the more essential elements of the gland-structure. It is very hard to see why such a tissue, which takes no active part in the changes going on in the gland, should be the starting-point of all the serious morbid alterations which occur. The idea, I believe, has arisen from a supposed analogy between cirrhosis of the liver and the so-called chronic inflammatory disease of the kidney. Cirrhosis was considered to depend upon inflammation, thickening, and subsequent contraction of another supporting fibrous tissue (Glisson's capsule), which was supposed to surround the lobules of the liver, and by its contraction to press upon the vessels. ("On Cirrhosis of the Liver," *Archives of Medicine*, Vol. I., p. 118.) For the origin of these morbid changes, we must look to the altered actions going on in the secreting structure, and not to inflammations

of tissues of doubtful existence, which take no part in the nutritive operations or gland-functions. The conclusions to which I have arrived from my own observations, with reference to the nature of the so-called matrix in the healthy kidney, and the changes taking place in disease, are at variance with those usually entertained both in this country and on the continent. The discussion of this question involves the whole subject of areolar tissue and its corpuscles. For an admirable statement of the opinions generally held, with many original observations, I must refer to a work by Arnold Beer, lately published in Berlin ("*Die Binde-Substanz der Menschlichen Niere*"). The drawings accompanying this work appear to me rather rough. The engraver, perhaps, has misinterpreted some of the author's representations.

Acute Nephritis.—The changes which I have described and figured in the kidney, in a case of acute nephritis, are of the greatest general interest. The case occurred in the practice of Mr. Image, of Bury St. Edmunds. The patient was 33 years of age, and was operated on for strangulated hernia. Four days after the operation, erysipelas appeared, which subsided in the course of three days. The day after the erysipelas disappeared, the urine which had hitherto been healthy, was found to contain albumen, blood-casts and blood corpuscles. The man died nineteen days afterwards, the *urine having been nearly suppressed for the last three days of his life.* There was anasarca but no disturbance of sensory or motor power, and no vomiting. The casts in the urine, three days before death, are represented in Plate X., Fig. 51, and in Fig. 52 a portion of a cast is shown, magnified 700 diameters. It contains in its *central part,* blood corpuscles and bodies like white blood corpuscles, which appear to be *undergoing multiplication* in the cast. The kidneys were much enlarged; one weighed 13 and the other 15 ounces. Now this considerable increase in weight was mainly due to the accumulation of matters in the capillary vessels and in the secreting tubes. The vessels were distended with large cells like white blood corpuscles (Plate X., Fig. 53), and the tubes were filled with casts and cells like pus corpuscles. Now, there can be little doubt that the cells represented in Fig. 53, in the capillaries, have been formed from the white blood corpuscles, and it is almost certain that the pus-like corpuscles in the *centre* of the cast have the same origin. The whole organ was passing into a state of suppuration, and the pus-like corpuscles in the urine of this

Fig. 49.



× 400

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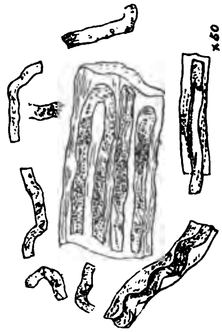
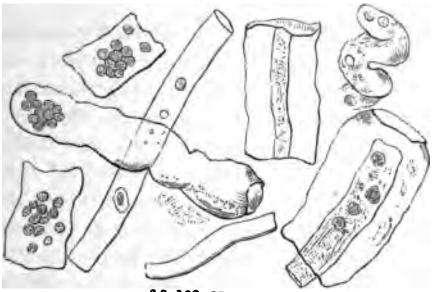
Fig. 50.



§ § 105, 371

Fig. 51.



§ § 108, 371

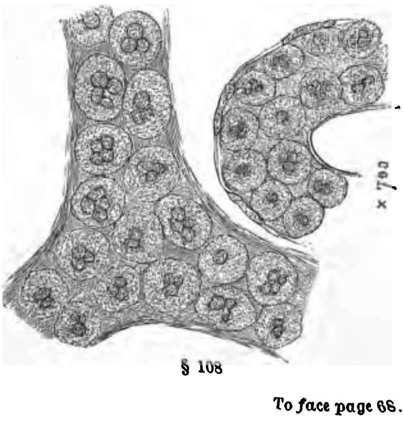
× 215

Fig. 52.

× 700

§ 108

Fig. 53.



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To face page 68.

case probably resulted from the multiplication of corpuscles in the tubes which were produced by the white blood corpuscles. (See "*Archives of Medicine,*" Vol. II., p. 286.)

Fatty degeneration.—In certain cases, the epithelium undergoes a very peculiar change, to which much attention has been given of late years. Fatty matter accumulates in the cells of the uriniferous tubes. The intertubular capillaries and those of the Malpighian bodies are also affected in a similar manner, and little collections of minute oil-globules may often be seen at intervals in their walls. This change often commences in a few of the tubes, and gradually extends until the whole organ is affected; but in some cases, only a few tubes here and there are affected by the disease, while many remain perfectly healthy. The kidney is in many instances much enlarged, while its colour has become very pale. Fatty degeneration, in many cases, is not confined to a single tissue or organ, but almost every part of the body is more or less involved.

109. Bright's Disease.—This term has been applied to all *morbid conditions of the kidney associated with albuminous urine.* Of late years, many important characters have been made out, by which we are enabled to distinguish several diseases of the kidney essentially different from each other—different in their origin, in their progress, and often in the results to which they lead. Dr. Johnson has accurately described several of these morbid changes, and his researches have been confirmed by other pathologists. However, some physicians still insist that the different conditions above alluded to are merely different stages of one and the same morbid process. Let any one examine carefully the small contracted kidney so commonly found in the bodies of old drunkards, with its rough puckered surface and diminished cortical portion, and contrast it with the large, smooth, and pale kidney, in a state of fatty degeneration, which is not unfrequently met with in young people not more than twenty years of age. The causes of these diseases are different; the conditions under which they occur are different; and although the result is fatal in both, death occurs in a very different way. Their chemical characters are different; their microscopical characters indicate the occurrence of changes which are totally distinct. Again, the treatment required in the early stages of these diseases, when alone any benefit is likely to be derived from treatment, is different.

The divisions and nomenclature adopted by Dr. Johnson are the following: *Acute desquamative nephritis; Chronic desquamative nephritis; Waxy degeneration of the kidney; Non-desquamative disease of the kidney; Fatty degeneration of the kidney; Suppurative nephritis.* Dr. Johnson still supports the same classification, and opposes the theory held by some pathologists with reference to the *oneness* of Bright's disease. He has recently written a paper on this subject, which will be found in Vol. xlii. of the "*Medico-Chirurgical Transactions.*" Dr. Johnson says, with regard to the oft debated question if large kidneys, at a subsequent stage of the morbid changes, contract, "The *rule* is, that a large Bright's kidney remains large to the end, and does not become a small one; and, on the other hand, a contracted Bright's kidney does not pass through previous stage of enlargement."

CHAPTER V.

HEALTHY URINE. *General Characters—Note-Book—Conical Glasses for examining Urine—Quantity of Urine—Colour of Urine—Smell of Urine—Clearness or Turbidity—Consistence—Deposit—Specific Gravity—Methods of taking the Specific Gravity—Reaction—Acid Urine—Alkaline Urine—Volatile and Fixed Alkali.*

IN the present Chapter, the general characters of healthy urine, which are of the greatest interest in a clinical point of view, will be briefly described. It is very important that the observer should, at once, acquire the habit of recording the results of his examination; and I therefore strongly recommend everyone to keep a note-book.

110. Note-Book.—The result of every observation should be carefully entered in a *note-book* at the time it is made; and it is often of the greatest importance to make a sketch of the microscopical characters of a deposit, and to append a careful but short description of the specimen at the time the drawing is made, as well as notes of the case from which the urine was obtained. (On drawing and measuring objects, see "*The Microscope in its Application to Practical Medicine*," 2nd edit.; refer also to § 33, and to Plate V., Fig. 22, of the present Work.)

Now, suppose a specimen of urine brought for examination, how is the investigation to be commenced? What are the first points which should attract notice? In what order should they be observed? And how is the nature of the constituents which are dissolved in the fluid, or which form a visible deposit, to be ascertained?

The perfectly fresh urine should be poured into a conical glass vessel (Plates I. and II., Figs. 6, 7, 9, § 12). If any deposit is formed, it must be subjected to examination in the microscope

(Chapter III.), and certain chemical reagents must be applied, as described under the head of "Urinary Deposits." The chemical examination of the fluid will be described after the general characters of healthy urine have been considered.

111. **Quantity of Urine.**—It is very important in all cases to know the quantity of urine passed in a given period of time. The most minute chemical and microscopical examination often fails to show any fact of importance in the investigation of a case, in consequence of the quantity of urine passed in the twenty-four hours not having been measured. The practitioner desires to know, not only the quantity of urine passed (that is, water and solid matter together), but in many cases it is necessary to be acquainted with the absolute amount of solid matter dissolved in the water. For this solid matter consists mainly of substances resulting from the disintegration of tissues and blood corpuscles. Such information can only be obtained by carefully measuring the entire quantity of urine passed in twenty-four hours, and evaporating a given amount of the *mixed urines passed at different periods of the day* to dryness. From the result obtained, the entire amount of solids passed can easily be calculated.

The amount of urine and the proportion of solid matter it contains vary very much, from day to day, in healthy persons. The temperature of the air, and the amount of moisture present in it; the state of the skin and mucous surfaces generally; the activity of the functions of respiration and circulation; the amount of exercise; the quantity and nature of the food, and, of course, the amount of fluid taken—are some of the circumstances which affect the *quantity* of the urine passed. But the quantity of urine in health varies according to the size of the individual, or rather according to the weight and the activity of the nutritive changes, so that it is quite useless to put forward with confidence any definite amount as the average quantity of urine passed by individuals generally. The nature of the occupation also materially influences the amount passed. In round numbers, however, the proportion in health may be estimated at from twenty to sixty ounces; and a greater quantity is passed in the winter than during the summer months, because in cold weather less fluid escapes from the body through the skin. It is stated that rather more than two ounces of urine are secreted per

hour, but during some periods of the day the secretion is much more active than at others.

112. Colour of Urine.—Urine from the same individual varies much in colour at different times, and specimens taken from a number of persons in a state of health exhibit the greatest variation in tint. Nevertheless, important information is often gained by observing the colour of urine. In some cases, from the colour, we are led to suspect the presence of certain substances dissolved in the fluid; in others, we may feel sure that certain morbid constituents are not present. The colour of the urine, as well as many other characters, seems to be affected by the period of the day, the nature of the diet, the state of the respiratory process, changes of temperature, and many other circumstances. Healthy urine varies from a pale straw colour to a brownish yellow tint. In disease, it may be perfectly colourless, of a natural colour, bright yellow, pinkish brown, of a smoky appearance, blood-red, or even dark blue. What we learn from these differences in colour will appear when we come to consider the characters of the urine in disease. Urinary *deposits* also vary much in colour: they may be white, pink, red, pale or dark brown, blue or black.

The nature of the colouring matters of urine has been carefully investigated by Heller, who obtained a yellow colouring matter, *uroxanthin*—corresponding closely to vegetable indican. This substance was also detected subsequently by Dr. Schunk, of Manchester. Prout had obtained indigo from urine, and had sublimed it in 1840. Uroxanthin can be decomposed by acids, or even by exposure to the air, into a red colouring matter, *urrhodine;* and a blue substance, *uroglaucine.* The former has the same composition as *indigo red;* the latter, as *indigo blue* ($C_{16} H_5 N O_2$). Uroglaucine, analogous to the blue compound obtained from indigo, may be obtained from all specimens of urine, and, in disease, sometimes forms a visible blue deposit. Indigo blue has nearly the same chemical composition as hæmatine: it is, doubtless, formed from it. Leucine, which has also been met with many times in urine, is another substance which may be produced in the formation of this blue deposit of indigo. The yellow colouring matter of healthy urine was termed by F. Simon, of Berlin, *hæmaphæin.* The presence of a substance in the urine from which indigo can be obtained must now be regarded as a settled fact; and it is

probable that the blue deposit observed in certain instances, and referred to by different authors, was indigo blue, formed by the decomposition of uroxanthin. Dr. Hassall has published some interesting cases, and has very carefully analysed the deposit ("*Philosophical Transactions*," 1854, p. 297; "*Proceedings of the Royal Society*," June 16th, 1853). I can fully confirm his statements, as I have recently had an opportunity of examining a specimen of urine with blue deposit, which was sent to me by my friend Dr. Eade, of Norwich.* In this case, the deposit was crystalline.

Uroërythrine is another colouring matter described by Simon, and always associated with uric acid and urate of soda. This substance is probably the *rosacic acid* and *purpurate of ammonia* of Prout, and the *purpurine* described by Dr. Golding Bird. It has been analysed by Scherer, who finds that it contains about 65 per cent. of carbon. It would seem that, when the elimination of substances from the liver, rich in carbon, is interfered with, an increased quantity of this substance is excreted in the urine. A green colour has been noticed in certain cases (Parkes). Creosote and tar, when taken internally, sometimes cause the urine to be of a very dark colour. Dr. Harley finds that the colouring matter of healthy urine contains a notable quantity of iron, like the hæmatine of the blood; and he gives to it the name of urohæmatine. Prout believed that the colouring matter of urine was due to the presence of a sort of resin; and Dr. Harley has lately isolated a resinous substance, which possesses many characters in common with the resin derived from certain plants, and closely resembles draconine, which is obtained from dragon's blood, the exudation from the stem of one of the resin-bearing palms.

The relation of the colouring matters of the urine to those of the bile has been dwelt upon, and Berzelius long ago drew attention to the resemblance of the latter to the chlorophyll of plants. Certain chemical reagents cause the same change in both these colouring matters. A red colouring material is not unfrequently seen in the cells in the central part of the lobules of the liver, and Dr. Bence Jones met with a gall-stone of a brick-red colour. There is much reason for believing that the formation of these colouring matters is connected with the disintegration of blood-corpuscles, and the quantity formed and the intensity of the colour probably depend

* "*Archives of Medicine*," Vol. I.

upon the activity of the oxidising processes going on in the organism; but the whole question of the production of colouring matter in the living body is still involved in great obscurity. The separation of a substance from the urine, from which indigo blue and indigo red may be prepared, must be regarded as a fact of the greatest interest; and further experiments on this subject are likely to lead to important results in connexion with the formation of organic colouring matters in the animal body. (*See* also § 210.)

113. Smell of Urine.—From the smell of the urine, in some instances, the practitioner may gain useful information. Healthy urine has a peculiar and very characteristic smell, which has been described as aromatic, but well known to all: it probably depends upon the presence of certain organic acids (Carbolic $C_{12}H_6O_2$). In disease, the specimen may be highly *pungent*, from the presence of *carbonate of ammonia*, which is produced by the decomposition of the urea excited by some animal ferment, especially by mucus of the bladder in a state of incipient decomposition. In other instances, it may have the smell of healthy urine, but the odour very much more intense. Sulphuretted hydrogen may be evolved from it. The smell of the urine is affected by many articles of food, such as asparagus, garlic, and cubebs. Turpentine, even if inhaled, causes the urine to evolve an odour something like the smell of violets.

114. Clearness of Turbidity.—Healthy urine is perfectly clear and transparent; but, after it has been allowed to stand for a short time, a very faint, flocculent, bulky deposit collects towards the lower part of the vessel. This cloud consists of a little mucus, with imperfectly formed epithelial cells from the mucous membrane, and epithelial *débris*.

In disease, the urine may be opaque, from the presence of different substances held in suspension. *Urate of soda* is the most frequent cause of this opacity, in which case the colour of the mass is generally of a dirty yellow, or brownish, resembling peas-soup. Very rarely it results from fatty matter in a minute state of division, and the urine has the appearance of milk. This occurs in cases of *chylous urine*. In these instances, the turbidity still continues after the urine has been allowed to stand still for some time; but generally the opacity of a specimen depends upon the presence of a deposit temporarily suspended in it from agitation, but which collects at the

bottom of the vessel after a time, forming a visible deposit, leaving a perfectly clear fluid above it.

115. Consistence.—Healthy urine is perfectly limpid, like water, and can be readily made to drop from a tube. In disease, however, the urine may be *slightly viscid*, or so *thick* and *glairy*, or *ropy*, that it may be drawn up at the end of a rod like a thread, and cannot be made to drop at all. It may be *semi-fluid;* and in rare instances, although passed perfectly fluid, it has afterwards assumed the form of a thick *firm jelly*, so that the vessel containing it might be inverted without its escape. Such specimens have been met with, associated with a milk-like appearance, in cases of *chylous urine.*

116. Deposit.—The only deposit which urine in health contains is the faint unimportant mucus-cloud before referred to (§ 114). All the constituents removed from the organism in this excretion, in health, escape in a perfectly soluble form; but when the healthy physiological changes are in any way interfered with, some of these constituents are produced in abnormal quantity, and are deposited, in an insoluble form, either at the time the urine is secreted, while it remains in the bladder, or at a variable interval of time after it has been passed. The deposit may be soluble in the warm fluid precipitated as soon as it becomes cold, or its deposition may be due to certain chemical decompositions occurring in the fluid.

117. Specific Gravity: proportion of Solid Matter.—By ascertaining the specific gravity of a specimen of urine (§ 23), we are enabled to form a rough estimate of the quantity of solid matter dissolved in the fluid; and, by measuring the entire quantity of urine passed in the twenty-four hours, we have data for judging approximately of the quantity of solid material removed from the organism in this secretion in twenty-four hours.

The specific gravity of healthy urine may be considered to be about 1,015, and the quantity of solid matter passed in the twenty-four hours, amounts to from 800 to 1,000 grains. It has been considered sufficient to calculate the quantity of solid matter from the specific gravity, by multiplying the number over 1,000 indicating the specific gravity, by about 2·5. The result will give an approximation to the quantity of solid matter in 1,000 grains of urine. This calculation is by no means correct, and is useless for accurate

investigations. Its inexact nature is shown by the fact that three very different numbers have been proposed, namely, 5·58, 2·33 and 1·65. When it is considered how widely different the composition of the solid matter may be in various specimens of healthy urine, it is obvious that results obtained in this manner must often be very wide of the truth. Take, for example, *albumen and common salt.* A fluid containing 136·4 grains of the former in 1,000 grains will have a specific gravity of 1,030; while one containing only 80·0 grains of common salt in the same quantity will have a specific gravity of 1,064. The proportion of common salt in urine varies more than the other constituents, as it depends upon the quantity taken in the food.

This clearly shows that any attempt to *calculate* the quantity of solid matter in an animal fluid cannot be very exact. In investigations, therefore, where any approach to accuracy is required, we must evaporate a given quantity of urine (1,000 grains) to dryness, at a low even temperature, and weigh the solid matter. As, however, this operation takes some time, physicians are compelled, as a general rule, to be content with taking the specific gravity. In many cases, the information gained by this simple operation is very important. Thus the urine may be not more than 1,002 or 1,003—a condition commonly met with in hysteria. A patient may be continually passing urine of specific gravity 1,010 to 1,012, which is commonly the case with albuminous urine, passed by patients suffering from certain chronic kidney diseases. Urine, containing a very large quantity of urea, so much that crystals of nitrate of urea are formed upon the addition of nitric acid without previous concentration *(excess of urea)*, usually reaches 1,030, or a little higher; and in cases of confirmed diabetes, where very large quantities of sugar escape from the organism, the urine has a specific gravity of 1,035 to 1,040, or even higher.

118. Reaction.—The reaction of urine may be readily ascertained by the use of litmus-paper, which is prepared by soaking a thin but firm smooth paper in an infusion of litmus. It is desirable not to use blotting-paper, or any spongy form of paper, for this purpose. Urine, having an *acid* reaction, immediately reddens this blue paper. The *alkaline* reaction of urine is ascertained by the use of *reddened litmus-paper,* prepared by adding a very small quantity of dilute

acid to the infusion of litmus. An alkali always restores the *blue* colour of this reddened paper. If no change occurs when the urine is tested with both kinds of paper, the reaction of the specimen is *neutral.*

119. Acid Urine.—The cause of the acid reaction of urine is obscure, and probably does not always depend upon the presence of the same substance. Sometimes the reaction may depend upon carbonic acid, which is present in greater or less proportion in all the animal fluids. In this case, the blue colour of the paper is restored by gently warming it after it has been changed by the acid. A fixed acid reaction may be due to the presence of an acid phosphate of soda—a salt which exhibits an acid reaction, without the presence of any free acid. This salt may be formed by the action of uric acid upon common rhombic phosphate of soda. If a little uric acid be added to a solution of common rhombic phosphate of soda, the mixture will, while cold, exhibit the characteristic alkaline reaction of the salt; but, when heat is applied, decomposition occurs; the uric acid disappears, and combines with one equivalent of the soda to form urate of soda; and an acid phosphate of soda is produced (experiment). The acid reaction of urine, however, cannot always be explained in this manner; and it is certain that traces of free organic acids are present. Lehmann has found both free lactic and free hippuric acids in some specimens of urine. Lately, Hallwachs has shown that a large amount of hippuric acid salts exists in healthy human urine.

Many specimens of urine which are slightly acid when passed from the organism, become more strongly so after standing for some days, and crystals of uric acid are deposited. The acid reaction may remain for weeks or even months, but usually the acidity gradually diminishes, and the specimen at last becomes alkaline from the presence of carbonate of ammonia, formed in consequence of the decomposition of the urea. The researches of Scherer have proved that the gradually increasing intensity of the acid reaction, and the deposition of uric acid, were due to a process resembling fermentation, which was excited by the presence of a small quantity of mucus.

The intensity of the acid reaction of urine in health is continually undergoing change at different periods of the day. Dr. Owen Rees,

in 1851, stated that "the degree of the acidity of the urine may, to a certain extent, be regarded as a measure of the acidity of the stomach" (Lettsomian Lectures, "*Medical Gazette*," Vol. XLVIII., 1851). Dr. Bence Jones has also made some highly interesting observations, which prove that the acidity of the urine alternates with that of the gastric juice. When the largest quantity of acid is being set free from the stomach, the acidity of the urine is at its minimum; and when the secretion of gastric juice is diminished, the urine exhibits a most strongly acid reaction. The urine passed just before each meal, or a long time after taking food, is intensely acid, while that which is secreted during the digestive process, for about three hours after a meal, is very slightly so, and in many instances it is decidedly alkaline. It is especially important to bear in mind the existence of these variations in the acidity of the urine in a state of health, and not to refer the intensely acid reaction of urine, secreted while no food is taken, to a morbid process requiring the exhibition of large doses of alkalies ("*On Animal Chemistry*," by H. Bence Jones, M.A., M.D., F.R.S.). Dr. Beneke has made upwards of one hundred experiments upon healthy and diseased persons without being able to confirm Dr. Bence Jones' observations. In only one case did he find the urine alkaline after meals. Sometimes the acidity was less, but this was not invariably the case. Nevertheless, he admits that the acidity of the whole amount of urine passed varied considerably, although he could not discover the cause. It seemed to be independent of the quantity passed, and was not affected by exercise or food ("*Archiv des Vereins für gemeinschaftliche Arbeiten zur Förderung der wissenschaftlichen Heilkunde*," 1 Band. 3 Heft.). Vogel, on the other hand, found that urine passed during the night was more acid than that secreted during the digestive process. Although the urine is by no means invariably alkaline, the acid reaction is always less intense after a meal. Dr. Roberts, of Manchester, has performed a very extensive series of experiments upon this question ("*Memoirs of the Literary and Philosophical Society of Manchester*," Vol. XV., 1859). He comes to the conclusion that, in two or three hours after a meal, the *acidity of the urine is diminished*, but that the secondary or remote effect of a meal is to *increase the acidity* of the urine. These results occur on an animal and also on a vegetable diet. Dr. Roberts considers that the above effects of the meal are due to the mineral constituents of

the food, which contain alkali in excess of the phosphoric acid present. Hence arises the alkalinity of the blood; but if this increases beyond a certain point, the kidneys separate the excess, and the urine is alkaline. If, on the other hand, the blood is not sufficiently alkaline, the kidneys separate acid. Thus do these organs regulate the quantity of alkali in the blood.

The intensity of the acid reaction is readily determined by ascertaining how much of a graduated solution of carbonate of soda is required to neutralise the acid in a given quantity of urine. In stating the results, the degree of acidity is expressed as if it depended on oxalic acid. In twenty-four hours, a proportion of acid is excreted which corresponds to from 30 to 60 grains of crystallised oxalic acid, according to Vogel.

120. Alkaline Urine.—The alkaline reaction of a specimen of urine may be due to the existence of carbonate of ammonia, in which case the blue colour produced by testing it with reddened litmus is destroyed by the application of a gentle heat (*volatile alkali*); or it may depend upon the presence of an alkaline carbonate, as carbonate of soda, or a neutral salt having an alkaline reaction, like common phosphate of soda, in which cases the application of heat does not restore the red colour of the litmus-paper (*fixed alkali*).

121. Volatile Alkali.—The development of carbonate of ammonia in urine depends upon the decomposition of the urea by the action of the mucus or some animal matter, which acts the part of a ferment. In some diseases of the mucous membrane of the bladder, and in cases of paraplegia, where the muscular coat of the organ is paralysed, and consequently the secretion is retained for a long time, this change is very liable to occur, and gives rise to pain and great distress, which are much relieved by washing out the bladder thoroughly with tepid water. A mere trace of urine which has undergone this change is capable of exciting a similar decomposition in a very large quantity. It is important to notice that if pus be present in such urine, it becomes coverted into a viscid glairy mass, which is removed from the bladder with the greatest difficulty. This action of the volatile alkali on the pus, precisely accords with that which occurs if ordinary liquor potassæ be added to a specimen of pure pus out of the body. Pus thus rendered glairy, forming a

viscid adhesive mass at the bottom of the vessel containing the urine, is usually called *mucus*, but as I have said, it really consists of altered pus. If this action on the pus only occurs after the urine has left the bladder, it is unimportant, but when it occurs before its expulsion, it is always necessary to interfere, and if the change cannot be entirely prevented, owing to the existence of certain mechanical impediments to the escape of the urine, we must try to render the urine acid, and thus prevent its occurrence, by giving very large and frequently repeated doses of nitric acid, unless this treatment is contraindicated, as in certain cases which I shall have occasion to refer to.

Whatever causes prolonged retention of the urine in the bladder, in the ureter, or pelvis of the kidney, will excite this change, and, as a consequence, roughening and ulceration of the mucous membrane ensue, with the precipitation of phosphate of lime and ammoniaco-magnesian phosphate. More pus is formed, which effects the decomposition of the urea and aggravates the mischief already produced, and unless relief be afforded, complete disorganisation of the mucous membrane results. Volatile alkali is never detected in healthy urine.

122. **Fixed Alkali.**—Urine, however, often exhibits an alkaline reaction due to the presence of an alkali which is not volatile by heat, and this reaction is often to be met with in a state of health. When an alkaline carbonate is detected in the urine, it usually results from the decomposition of salts of certain organic acids in the organism. Salts of tartaric, racemic, citric, and, under some circumstances, those of oxalic and acetic acids, become resolved into carbonates in their passage through the organism, just as by the influence of a red heat they are converted into carbonates out of the body. The urine may always be rendered alkaline, and very quickly so, by giving such salts in sufficient quantity; and their administration is of great advantage in cases where benefit is likely to be derived from alkalies, especially where strong alkalies do not agree with the digestive organs. I believe that in many cases the alkali thus formed in the organism exerts a more beneficial influence than the exhibition of alkalies or their carbonates. The value of the juice of oranges and lemons in various conditions is to be attributed to this change.

If the alkaline reaction of the urine is due to the presence of carbonate of ammonia crystals of triple phosphate ("*Illustrations*," Plate IX., Fig. 1; XXI., Figs. 1, 3), and a deposit of phosphate of lime in a granular state, or in the form of globules or minute dumb-bells, will be present; if, on the other hand, it depends upon fixed alkali, only the latter deposit without the crystals will be detected.

The quantity of alkali can be estimated by the ordinary process of alkalimitry. Dilute sulphuric acid containing a known quantity of pure sulphuric acid is added until the reaction is neutral to test paper.

Before resorting to a more complete chemical and microscopical examination of a specimen of urine, it is important to ascertain the *quantity* passed in twenty-four hours, to notice its *colour*, *smell*, *consistence*, *clearness*, or *turbidity*, and the presence or absence of a *deposit*, and to ascertain its *specific gravity* and *reaction*.

CHAPTER VI.

HEALTHY URINE. I. *Volatile Constituents.*—II. *Organic Constituents.*—III. *Inorganic Constituents*—VOLATILE CONSTITUENTS: *Water—Carbonic Acid—Ammonia and Ammoniacal Salts.* ORGANIC CONSTITUENTS: *Urea—Quantity—Characters—Circumstances affecting the Formation of Urea—Origin—Creatine—Creatinine—Guanine—Sarcine—Inosite—Uric Acid—Quantity—Detection—Mode of Formation—Urates—Hippuric Acid—Extractive Matters—Sulphur Compounds—Sugar—Mucus—Lactic Acid and Lactates—Oxalic Acid—Peculiar Organic Acids and Formic Acid.*

IT is convenient to divide the constituents of healthy urine into three classes, viz.:—

I. VOLATILE CONSTITUENTS;
II. ORGANIC CONSTITUENTS;
III. INORGANIC CONSTITUENTS.

The first class includes those substances which are volatilised at the temperature of a steam-bath (212° or less). The most important of these are, *water*, *carbonic acid*, and *certain ammoniacal salts.*

The second class contains those organic constituents which are not volatilised at a temperature of 212°, but which are decomposed at a red heat. The most important of these are, *urea*, *uric* or *lithic acid*, *hippuric acid*, with *urates* and *hippurates*, *lactic acid and lactates*, *mucus* from the bladder or other parts of the urinary mucous membrane; *creatine*, *creatinine*, and various indeterminate uncrystallisable substances included under the head of *extractive matters.* The *colouring matters* already described (§ 112), and certain

peculiar organic acids, traces of *sugar*, with perhaps traces of *leucine*, *tyrocine*, and one or two other less important organic matters, might be included in this class.

In the third class are found various *saline matters* which remain fixed after the organic matter has been destroyed by a red heat, and the carbon which results, removed by prolonged exposure to a dull red heat in contact with the air. These inorganic constituents consist principally of *chlorine*, *sulphuric* and *phosphoric acids*, and, in some cases, *nitric acid*, in combination with *sodium*, *potash*, *soda*, *lime*, *magnesia*, *iron*, and sometimes *alumina*, with traces of *silica*.

I. Volatile Constituents of Healthy Urine.

123. Water.—Healthy urine contains from 940 to 960 grains, or even more, in 1,000. The proportion of water is much influenced by various circumstances, especially by the quantity taken in the food, the activity of the skin, and the presence of various substances which influence the chemical changes going on in the tissues, or affect the secreting action of the kidneys. The mode of estimating the proportion of water has been before alluded to. At first this would be supposed to be a very simple matter, but in practice it is found to be one of the most difficult operations in analysis, because many of the organic constituents of urine are prone to undergo changes at a very moderate heat, and even at the temperature of the air, if the concentration is effected too slowly. Practically, it is the best plan to concentrate the urine at a temperature of 100°, and then continue the evaporation *in vacuo* over sulphuric acid until the residue ceases to lose weight (§ 10).

124. Carbonic Acid is held in solution in fresh urine: indeed, traces may be detected in all the animal fluids. Its presence may be shown by passing some pure hydrogen gas through urine. After the gas has traversed the urine, it should be conducted into pure lime water, which will become turbid if there be an appreciable quantity of carbonic acid present. This experiment is founded upon the fact that, if one gas be passed through a solution of another gas, the latter will be displaced by it. By distillation, also, the presence of carbonic acid may be shown; but, in this process, great care must be taken

to prevent the production of carbonate of ammonia, which would, of course, cause a precipitation of carbonate in lime or baryta water. The fluid may be made to boil at a temperature of 120, if the air be exhausted. There are certain peculiar volatile acids which will be described with the other acids of the urine (§ 150).

125. Ammonia and Ammoniacal Salts.—Another volatile constituent of urine is *ammonia*. The presence of this substance in healthy urine has been doubted by many; but Heintz has shown that the addition of chloride of platinum to fresh urine causes a precipitate which consists of the potassio-chloride of platinum, with a certain quantity of the ammonio-chloride of platinum; the amount of the latter being estimated by determining the quantity of the potassio-chloride in a separate experiment. Neubauer has obtained thirteen grains of ammonia from the urine in twenty-four hours. Ammonia exists as urate and lactate; it is also found in combination with hydrochloric acid, with phosphoric acid and soda, and with phosphoric acid and magnesia. Chloride of ammonium is also present. Neubauer and Kerner estimate the quantity of chloride of ammonium at about 35 grains in twenty-four hours.

Ammonia is likewise given off during the decomposition of several of the organic constituents of the urine by heat, as indeed it is from many other nitrogenous organic substances. Thus, if a portion of the solid residue of urine be exposed to a temperature short of redness in a small glass tube, much very offensive vapour will be given off, and a carbonaceous residue will remain in the tube. If a piece of reddened litmus or turmeric paper, moistened with distilled water, be applied to the mouth of the tube as soon as it is heated, the blue colour of the former will be restored, and the latter will assume a dark brown tint—reactions which indicate the existence of volatile alkali or ammonia, which arises from the decomposition of nitrogenous matters.

II. Organic Constituents of Healthy Urine.

Many of the constituents of healthy urine may be obtained in a crystalline form by allowing a few drops to evaporate, at a moderate temperature (about 140°), upon a glass slide, or in a shallow oval glass cell. In this manner, crystals of urea, urate of soda, chloride of sodium crystallised in cubes and octohedra, phosphates, and sul-

phates, may be readily obtained. The observer should make himself familiar with the appearance of these crystals. ("*Illustrations of Urine*," etc.; Urine, Plate I.)

The quantity of the organic constituents varies very much, as would be supposed. In healthy urine, about three-fourths of the solid matter consists of organic substances, and there may be found from 12 or 14, to 45 or 50 grains in 1,000 grains of urine. The mode of estimating the amount of solids has been already referred to (§§ 123, 10). The quantity of the organic constituents is easily obtained by burning a weighed portion of the solid matter, and by subtracting from the amount the quantity of saline residue which remains after incineration. The result gives the quantity of organic matter.

126. Urea ($C_2\ H_4\ O_2\ N_2$).—The most important of the organic constituents of urine is urea. It is a crystalline substance, very soluble in hot water, and in four or five parts of cold water, soluble in alcohol, but insoluble in pure ether, deliquescent, readily crystallised if pure, but the presence of some organic constituents seriously interferes with its crystallisation. However, good crystals of urea may often be obtained by simply evaporating a specimen of urine upon a glass slide, at a moderate temperature. Urea has a cool saline taste, is perfectly colourless when pure, but has a very strong affinity for the colouring matter of urine. In order to obtain perfectly colourless urea from urine, it is necessary to expose it to the prolonged action of animal charcoal in a diluted state.

127. Quantity.—Urine in health contains from 12 or 15 to 30 or 40 parts of urea per 1,000; and as much as from 400 to 600 grains of solid urea are excreted from the body of a strong healthy man in twenty-four hours. The solid matter of healthy urine contains half its weight of pure urea. The amount of urea excreted in twenty-four hours, corresponding to each pound weight of the body, is about 3·5 grains. So that a healthy man, weighing about 140 lbs., ought to secrete during the twenty-four hours nearly 500 grains of urea. In infants and children, however, a much larger quantity in proportion to the weight of the body is secreted. From some calculations of Dr. Parkes, based on analyses made by Scherer, Rummell, Bischoff, and Lecanu, it appears that a child, weighing

about 30 lbs., and four years of age, will excrete for each pound weight of the body nearly 6 grains of urea in twenty-four hours.

The Rev. S. Haughton (a paper read before the Association of the King and Queen's College of Physicians, Dublin, 1860) has endeavoured to show that of the urea excreted certain proportions represent the *vital*, *mechanical*, and *mental* work performed in the organism. Men employed in ordinary routine bodily labour may be well fed on a vegetable diet, and discharge 400 grains of urea daily, of which 300 grains are spent in *vital*, and 100 grains in *mechanical* work. If the work is of a higher order, better food must be supplied, and 533 grains of urea are excreted. Of this quantity 300 grains are spent in *vital*, and 233 grains in *mental* work and *the mechanical* work necessary to keep the body in health.

128. Detection.—*Nitrate of Urea.*—The presence of urea is very easily detected, if the solution be moderately strong. If a few drops of strong nitric acid be added to urine which has been slightly concentrated by evaporation, and afterwards allowed to cool, a number of beautiful sparkling crystalline lamellæ immediately make their appearance. These crystals of *nitrate of urea* are not very soluble in the solution, and are easily recognised by their microscopical characters (Plate XI., Fig. 55). ("*Illustrations of Urine,*" Plate III.)

Oxalate of Urea.—If, instead of nitric acid, a concentrated solution of crystals of oxalic acid be added to the concentrated urine, numerous crystals of *oxalate of urea* would be formed. The oxalate is also a very insoluble salt, and, like the nitrate, crystallises in rhomboidal plates; but the crystals are more perfectly formed, and the inclination of the angles is different (Plate XI., Fig. 56). ("*Illustrations of Urine,*" Plate IV.)

A solution of pernitrate of mercury also forms a precipitate with urea; but, in order to apply this test, all the chloride of sodium and phosphates must be removed. Liebig has proposed a most simple and highly efficacious plan for estimating the quantity of urea by ascertaining the amount of a solution of pernitrate of mercury, of known strength, which is required to throw down the whole of the urea in a given volume of urine. This process for estimating the quantity of urea, as well as the simple plan proposed by Dr. Davy, has been described in § 39. Other plans of estimating urea have

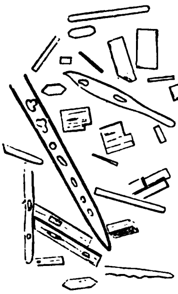
been proposed, but they are more complicated than those already described. Urea in solution is decomposed by nitrico-nitric acid, carbonic acid being rapidly given off. Draper's process is founded upon this fact ("*Phil. Mag.*," Vol. VI., Series IV., p. 290). Bunsen and Ragski have recommended other methods based upon the decomposition of urea into carbonate of ammonia. By ascertaining the quantity of carbonic acid or of ammonia formed, the proportion of urea can be calculated ("*Quarterly Journal of Chemical Science*," Vol. I., p. 420).

129. Characters.—Urea crystallises in four-sided prisms, which seem to be composed of a number of acicular crystals (Plate XI., Fig. 54). ("*Illustrations of Urine*," &c., Plate II., p. 56.) It melts at 248°, and is decomposed at a higher temperature; cyanate of ammonia and carbonate of ammonia being among the products of the decomposition. It is not decomposed by being boiled in pure water, but mere traces of putrescent animal substances excite rapid decomposition even in the cold. Yeast also exerts the same effect; and mucus and pus produce this decomposition very rapidly, as already remarked under the head of "volatile alkali" (§ 121). The rapid evolution of carbonate of ammonia from urine which has been placed in a dirty vessel, is explained in the same manner.

It is curious that urea causes common salt, which, under ordinary circumstances, crystallises in cubes, to crystallise in octohedra; and chloride of ammonium, which crystallises in octohedra, to crystallise in cubes.

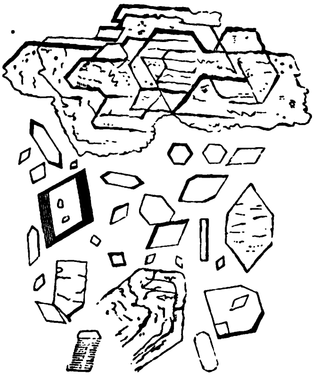
In the laboratory, urea may be formed artificially. By allowing cyanate of ammonia to evaporate to dryness, it becomes converted into urea, in which neither cyanic acid nor ammonia can be detected. Urea is one of the products formed by the action of peroxide of lead on uric acid, and it is also produced by the action of alkalies upon alloxan and creatine. Béchamp stated that he had obtained urea directly from the action of oxidising substances on protein compounds, as permanganate of potash upon albumen. This experiment has been many times tried in my laboratory without success, and several chemists have failed to confirm Béchamp's results; so that we may consider that, up to the present time, no one has succeeded in producing urea directly from the tissues, or from albuminous substances.

Fig. 54.



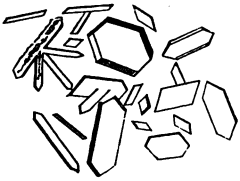
§ 126 × 215

Fig. 55.



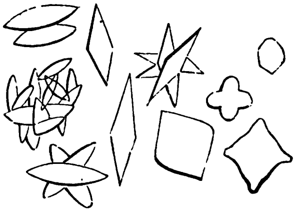
§§ 128, 203 × 215

Fig. 56.



§ 128 × 215

Fig. 57.

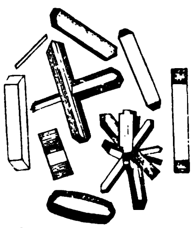


§ 135 × 215

Fig. 58.

§ 140

Fig. 59.



§ 132

Fig. 60.

§§ 134, 321

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If it is desired to obtain a specimen of pure urea from urine, an *oxalate or nitrate* is first prepared, purified by being recrystallised, dissolved in water, and heated for some time in contact with pure animal charcoal. When the solution is colourless, it is decomposed with chalk or carbonate of barytes. The urea is separated by alcohol, and the solution concentrated, so that crystals may form. The pure crystals are very deliquescent; but they may be dried and preserved for any length of time, if carefully excluded from the air. They form beautiful microscopic objects.

Rich in nitrogen, very soluble in water, readily diffused through large quantities of fluid, and possessing considerable power of permeating animal membrane, urea may be regarded as the principal product resulting from the disintegration of nitrogenous tissues, (probably immediately from the red blood corpuscles), and as one of the most important excrementitious substances from the animal organism. Not only is urea derived from the products resulting from the disintegration of muscular fibre, but any excess of albuminous materials taken in the food is removed from the body chiefly in the form of urea. It must, however, be borne in mind, that the urea does not exist in the fluid expressed from the muscles: it is probably formed in the blood.

130. Circumstances affecting the Formation of Urea.—The quantity and nature of the food, and all circumstances which affect the nutrition and repair of the tissues, will exert an influence upon the quantity of urea formed in a given time. A liberal diet, rich in albuminous substances, and active exercise, combined with a healthy state of the organs of respiration and circulation, cause the formation of a large quantity of urea; while indolent habits, a diet rich in carbon and poor in nitrogen, insufficient food of any kind, an unhealthy state of the lungs and circulatory organs, and an imperfect supply of good air, will diminish the proportion formed. It need hardly be said that a greater quantity of urea is formed during the day than during sleep; by strong muscular persons, than by weak ones; by men than by women; in winter, when a small quantity of excrementitious substances are removed by the skin, than in summer, when the perspiration is abundant.

In all probability, urea is formed in the organism by the oxidation of uric acid and other substances. If the oxidising

processes in the body are active, these substances become ultimately resolved into urea and carbonic acid; but if, on the other hand, these processes are less active than they should be, the uric acid does not undergo further decomposition. A certain quantity of oxalic acid, and other substances of a lower degree of oxidation than urea, seem to be produced, and instead of the greater part of the comparatively insoluble uric acid being resolved into soluble urea, an increased quantity is found in the urine. Wöhler and Frerichs have shown that, if uric acid be taken at night, oxalate of lime is found in the morning urine; and Neubauer found that, when rabbits were made to take a considerable quantity of uric acid with their food, the urea in their urine increased from 1·34 to 4 grammes (from 20·67 to 61·72 grains). Large quantities of fluids cause an increase in the proportion of urea formed in the organism. A dilute state of the solids is favourable to their oxidation; and in certain conditions, where these changes are but imperfectly carried on, and in consequence uric acid accumulates in the blood, or at most is resolved into oxalic acid, the further oxidation is promoted by the administration of increased quantity of fluid, especially of fluids containing alkalies which not only increase the activity of the changes, but effect the solution of the insoluble uric acid and urates. Hence the benefit of alkaline waters, baths, moderate exercise, and plenty of good air, in gout and other conditions in which much more uric acid is formed than can be, under ordinary circumstances, converted into urea.

The quantity of urea excreted is also increased by common salt (Bischoff). It is probable that not only does cloride of sodium, so to say, filter through the different tissues, like other saline substances, and thus drive out other materials which are contained in their interstices; but that it also facilitates the occurrence of chemical change in the body, and directly influences the quantity of urea formed. The importance of chloride of sodium in cell-growth, during the development of different textures, and its value in nutrition generally, are well known.

The beneficial effect of alkalies in different cases is acknowledged by all; and it is probable that this is in part to be explained by the influence they have been proved to possess in promoting chemical change in the body, and especially in favouring the oxidation of albuminous substances. Dr. Parkes has shown conclusively, in an elaborate series of experiments, that liquor potassæ exerts a direct

influence of this kind. ("On the Action of Liquor Potassæ on the Urine in Health," *British and Foreign Medico-Chirurgical Review*, Vol. XIV., p. 258, January, 1853.) The per centage of solids in the urine is increased, the urea seemed to be increased somewhat; but Dr. Parkes considers this only a probable effect of the alkali. The proportion of sulphates was augmented in all the experiments. Franz Simon long ago showed that the sulphates were always increased whenever an increased proportion of urea is formed; and the more recent researches of Dr. Bence Jones lead to the same conclusion. In Dr. Parkes' experiments, the acidity of the urine was hardly affected by the liquor potassæ; and the whole of the potash taken (2 drachms) was entirely excreted in the urine, in the form of sulphate, in a very short time,—if taken on an empty stomach, in from thirty to ninety minutes. Such facts assist in the most important degree to elucidate some of the most complicated chemical changes going on in the organism, and afford valuable information as to the nature of various morbid changes, as well as suggest the means by which these may be modified or counteracted. For these reasons, I have thought it desirable to dwell upon them rather at length.

On the other hand, both the solids (urea, extractives, uric acid, sulphuric acid by 13 grains, daily phosphoric acid, chloride of sodium very considerably), and fluid of the urine are diminished by alcohol; so also is the proportion of carbonic acid exhaled. Tea causes a diminution both in the quantity of urine and fæces, as the beautiful researches of Dr. Böcker have conclusively proved. ("Beiträge zur Heilkunde Vol. I.," *Medico-Chirurgical Review*, Vol. XIV.) Hammond's observations confirm Böcker's in the most important particulars ("*American Journal, Medical Science*," October, 1856). Coffee exerts a similar effect, which seems to be due, not to the caffeine, but to the empyreumatic oil which it contains, according to Julius Lehmann. These substances, tea, coffee, and alcohol, in moderate quantity, affect the disintegration of tissue, and directly diminish the quantity of the excrementitious substances formed in the process. Supposing the food to be insufficient, the loss of weight which must necessarily take place in the body would be lessoned; and they may, therefore, be regarded as advantageous, not only in economising the food, but in limiting to some extent the waste of the albuminous tissues. Probably these substances directly interfere with the disintegration of the blood corpuscles.

131. Origin.—It has been concluded that urea is not formed in the kidneys, as it has been shown to exist in the blood. It is merely selected or separated from this fluid by the cells of the uriniferous tubes. At the same time it must be admitted, that it has not been proved, that no urea whatever is found in the kidneys. It is with difficulty detected in healthy blood, because it is prevented from accumulating in that fluid in sufficient quantity by the selective power of the renal epithelium.* If, however, the secreting action of the kidneys be impaired by disease, or if the blood be prevented from flowing through them, the urea will accumulate in the blood to a considerable extent, interfering with the function of other organs, especially the brain; and may in many cases be very readily detected by chemical tests.

Under these circumstances, an incomplete removal of the urea will take place through other channels. It has been detected in the fluids of the intestinal canal, in vomited matters, in the saliva, tears, milk, bile, and sweat, in serous fluids in different localities, in the liquor amnii, and in the fluids of the eye.

Urea cannot be detected in the muscles, but can be readily produced from several substances found in them; and it is therefore probable that, in the organism, urea forms the last of a series of compounds which results from the disintegration of the tissues, or more immediately from the disintegration of blood corpuscles. Removed from the body, very slight causes are capable of effecting its decomposition, and resolving it into ammonia and carbonic acid —substances of the highest importance to the growth of plants.

It has been generally concluded that any albuminous matters taken in the food, in excess of what is required for the nutrition of the system, is at once converted into urea. Bischoff and Voit have endeavoured to show, on the other hand, that in this and in all cases the urea results from tissue metamorphosis. It seems to me most probable that all pabulum entering the system must, before its elements can be applied to the nutrition of the tissues or be removed by the organs of respiration and secretion, be first of all taken up by cells (chyle corpuscles, white blood corpuscles), and become living or *germinal matter*, which, after passing through certain definite

* Dr. Thudichum attributes the failures of observers to detect urea in the blood, to their precipitating the albumen by heat. If the blood be treated with strong alcohol, the urea is dissolved, and the albumen rendered insoluble at the same moment. The former can be detected in the alcoholic solution.

stages of existence, becomes the *formed* matter of the red blood corpuscles. The products resulting from the disintegration of this formed matter may be taken up by the germinal matter of tissues, and at length become tissue, or by that of secreting cells, in which case it is removed from the body altogether.

132. **Creatine** ($C_8H_9N_3O_4$) exists in small quantity in urine. Its presence in this secretion was discovered by Heintz. Dr. Thudichum has obtained from 3·45 to 6·32 grains of creatine from the urine of a healthy man in twenty-four hours. The average is 4·7 grains. Creatine has a pungent taste, is very soluble in hot water, but requires about seventy-five parts of cold water for its solution. It is very slightly soluble in alcohol, and quite insoluble in ether. It crystallises in right rectangular prisms and rhomboidal crystals. ("*Illustrations of Urine*," Plate VII., Fig. 3.) By being boiled with baryta water, it is converted into urea and sarcosine; with strong acids, into creatinine.

Creatine may be obtained from urine by the following process, proposed by Liebig. Lime water and chloride of calcium are first added to the urine, which is then filtered and concentrated by evaporation, in order to remove most of the salts. The liquid from which the salts have been separated is decomposed with one-twenty-fourth of its weight of a syrupy solution of chloride of zinc. After the lapse of some days, a number of round granules made their appearance. These consist of chloride of zinc and creatinine, with which creatine is mixed. ("*Illustrations of Urine*," Plate VII., Figs. 1 and 2.) They are dissolved in hot water, and treated with hydrated oxide of lead until the reaction is alkaline. The oxide of zinc and chloride of lead are to be removed by filtration; and, after being decolorised by animal charcoal, the solution is evaporated to dryness. The residue is to be treated with boiling alcohol, which dissolves the creatinine very readily, but leaves the creatine, which may be recrystallised by solution in hot water. Crystals of creatine are represented in Plate XI., Fig. 59.

Creatine is obtained from all kinds of lean meat, but exists in larger proportion in that of mammalia than in birds, reptiles, and fishes. Gregory obtained ·14 from 100 parts of bullocks' heart, ·08 in 100 parts of pigeons' flesh, and 0·6 in the same quantity of the flesh of the skate. Although the flesh of fishes contains less creatine

than that of the higher animals, it is more favourable for extraction. I obtained more than seventeen grains of creatine from two pounds of the flesh of the crocodile. The presence of creatine has been detected in the blood by Verdeil and Marcet. Traces of it have been discovered in the amniotic fluid.

Its existence in the juice of muscular tissue, and its presence in the urine, would lead to the conclusion that creatine was one of the nitrogenised products resulting from the disintegration of muscular tissue; and such a view of its nature is supported by the readiness with which it is decomposed into urea, creatinine, and sarcosine. It is found in greater quantity in muscles which have been in active exercise during life, than in those which have been quiescent. The heart yields a large quantity; and more is found in animals which have been hunted to death than in those destroyed without being subjected to violent exercise. Creatine may, like urea, be regarded as an excrementitious substance.

133. **Creatinine** ($C_8H_7N_3O_2$) is also crystalline. The crystals take the form of right rectangular prisms, according to Robin and Verdeil. It has a strongly alkaline reaction, and is soluble in water. It is very soluble in warm alcohol. It combines with different acids to form salts. With chloride of zinc a crystalline compound is formed, composed of roundish wart-like masses, made up of minute radiating crystals, which have been already referred to.

Creatinine is found in the urine in larger proportion than creatine, and must be considered as an excrementitious substance. It is not destroyed in the decomposition of urine, while the creatine undergoes conversion into creatinine. Dr. Thudichum obtained as much as from five-and-a-half to nearly ten grains of creatinine from the urine of a healthy man in twenty-four hours.

134. **Guanine** ($C_{10}H_5N_5O_2$), **Sarcine, Inosite** ($C_{12}H_{12}O_{12} + 4Aq.$).—Strahl and Lieberkühn have discovered a substance in urine which they considered to be xanthine, but which, from its behaviour with reagents, may probably be regarded as guanine. Strecker has detected in urine a substance closely resembling sarcine, found in muscular fibre; but its exact nature is at present doubtful. Inosite has been found in the urine of a man suffering from Bright's disease by Cloëtta, but it has not yet been detected in healthy urine. Crystals of inosite are represented in Plate XI., Fig. 60.

135. Uric or Lithic Acid ($C_{10}H_4N_4O_6$).—The organic constituent of the urine which ranks next in importance to urea is uric or lithic acid. In healthy urine its presence cannot be detected, unless a small quantity of a stronger acid, as nitric or hydrochloric, be first added to decompose the soluble urates. After the mixture has been allowed to stand for some time, the uric acid separates in the form of small red crystalline grains, which adhere to the sides of the glass vessel. Upon microscopical examination, these are found sometimes to be composed of separate crystals, and sometimes of small stellate groups; the individual crystals varying in form from the lozenge-shape to that of an elongated crystal with sharply pointed extremities. ("*Illustrations*," Plate IV., Figs. 2, 3, 4, and 5.) Uric acid is a very weak acid, and is perfectly separated from its salts by acetic acid. It is soluble in solutions of alkaline lactates, acetates, carbonates, phosphates, and borates. Uric acid has the power of decomposing the alkaline phosphates. It takes a part of the base, forming a urate, and leaves an acid phosphate, as I mentioned when speaking of the acid reaction of urine. The colour of the crystals of uric acid which have been obtained from urine is derived from the proper colouring matters of the secretion, and must, therefore, be regarded as an impurity. It can easily be obtained perfectly pure and colourless; and, in three or four instances, I have observed perfectly colourless crystals of this substance, which have separated spontaneously from urine holding in solution scarcely à trace of colouring matter.

Pure uric acid crystallises in the form of very thin rhomboidal laminæ; but the sides of the crystals, instead of being perfectly straight, are usually more or less curved. The angles, again, are often rounded, so that the crystal has an oval form. In Plate IV., Figs. 2 and 5, and Plate V., Fig. 7, of the "*Illustrations*," some pure crystals of uric acid are represented. Some of these crystals were obtained by the addition of acid to the solution. Although uric acid may be perfectly pure, the crystals vary much in size and form (Plate XI., Fig. 57). Experiments show what very slight variations in the conditions under which they are produced are sufficient to determine great alterations in the form of the crystal.

136. Quantity.—Healthy urine contains from half a grain to a grain of uric acid in 1,000 grains of urine. The solid matter contains

about 1·3 per cent. of this substance, and probably from five to eight grains are excreted by a healthy adult man in twenty-four hours. Dr. Thudichum gives the latter as the average quantity. The quantity of uric acid excreted in twenty-four hours, for every pound weight of the body, amounts to ·059, according to Parkes.

137. Detection.—The chemical characters of uric acid are well marked.

1. If to a deposit consisting of uric acid, placed on a glass slide, a drop of nitric acid be added, a brisk effervescence ensues; and when the mixture is slowly evaporated over a lamp, a reddish residue is left. Upon the addition of a drop of ammonia, a rich purple tint is produced, owing to the formation of murexide, the so called purpurate of ammonia. This test is exceedingly delicate: it was first applied by Dr. Prout. One other substance possesses a similar reaction, and this is caffeine; but uric acid is at once distinguished from it by its microscopical characters.

2. The deposit suspected to contain uric acid or a urate may be dissolved in a drop of solution of potash, in which it is very soluble. Upon adding excess of acetic acid, and leaving the mixture for some hours, small crystals of uric acid will form. These may be recognised by their microscopical characters.

3. Uric acid may be detected in animal fluids, when mere traces of this substance or of urates are present, by a plan proposed by my colleague (Dr. Garrod). The fluid suspected to contain the urate is treated with a few drops of strong acetic acid (glacial acetic acid is best) in a watch glass. A few filaments of tow or very thin silk are placed in the mixture, and the whole set aside under a glass shade in a warm place, for twenty-four or forty-eight hours. Gradually uric acid crystals separate, and are deposited upon the filaments. Their characters may be recognised by microscopical examination. Some crystals of uric acid upon a hair are represented in Plate XXI., Fig. 6, of the "*Illustrations.*"

The quantity of uric acid is estimated by collecting the crystals separated by the addition of an acid, and weighing them after they have been carefully washed and dried. Dr. Thudichum recommends the use of nitric acid, because the uric acid is less soluble in it, and there is not so much tendency to the development of fungi as if hydrochloric be employed.

138. Mode of Formation.—Uric acid is found in the urine of most carnivorous animals, and in that of young herbivora while sucking, and, therefore, feeding upon a diet rich in nitrogen. It is not found in the urine of the pachydermata, not even in that of the omnivorous pig. It is abundant in the urine of birds, and is found in that of many reptiles and insects. Uric acid exists in the blood, and is only *separated* from that fluid by the kidneys. Dr. Garrod has detected it in the blood of men in health, and in cases of gout in considerable quantity. In such instances, uric acid crystals may be separated from the fluid obtained from a blister, according to the plan just described. It has been detected in the juice of the spleen in considerable quantity by Scherer, but Mr. Gray has failed to confirm these observations. Cloëtta has found it in the pulmonary tissue of bullocks' lungs, associated with taurine, inosite, and leucine. It has also been found in the brain and in the liver.

Uric acid, like urea, is one of the products indirectly resulting from the disintegration of albuminous tissues. It is probable that it results directly from the action of oxygen upon substances formed by the red blood corpuscles. The formation of a large quantity of uric acid by birds is a fact strongly in favour of Liebig's doctrine, that uric acid is first produced, and that this is afterwards converted into urea. Prout held "that a very large proportion of the urate of ammonia found in the urine on common occasions appears to be developed from the imperfect albuminous matters formed during the assimilating processes." This is rendered probable by the researches of later observers, especially by those of Bidder and Schmidt. Uric acid may be deposited, in combination with soda and lime, in various structures. It may accumulate beneath the skin, so as to form large collections, which are familiar to us under the name of chalk-stones. It is curious that these depositions should take place in areolar tissue, in white fibrous tissue, and in connexion with cartilage. Perhaps this may be connected with the very slight vascularity of these tissues when fully formed, although they are highly vascular during the early period of their growth; and it must be borne in mind that the deposits usually occur at a time of life when they are fully developed, after which they probably undergo very slight changes, and the processes concerned in their decay and regeneration are slowly and, perhaps, in sedentary

persons, very imperfectly carried on. These circumstances would favour the separation of a slightly soluble substance from the blood, and its deposition in an insoluble state. Lehmann has shown that, after attacks of disturbed digestion, the proportion of uric acid to the urea becomes increased. Alcoholic liquors seem to have the same effect. In normal conditions of the system, the urine contains about 1 part of uric acid to 28 or 30 parts of urea; but, under the circumstances just mentioned, the ratio becomes 1 to 23 or 26. This increased proportion of uric acid appears to be formed in consequence of the usual proportion not being converted into urea. Alcohol causes a diminution in the quantity of carbonic acid exhaled; and, in such cases, an increased proportion of uric acid, urates, and usually oxalates, is found in the urine.

A highly nitrogenised diet, with insufficient exercise—confinement in ill-ventilated rooms—all circumstances interfering with the healthy action of the respiratory apparatus—or preventing the proper amount of blood being carried to the pulmonary surface, active exercise in confined air, &c.,—are conditions favourable to the formation of an increased quantity of uric acid and urates. The formation of urea and oxalic acid from uric acid in the organism, or artificially by the action of peroxide of lead, has been previously alluded to. Ranke has shown that, at a high temperature, in the presence of yeast and an alkali, uric acid also becomes converted into urea and oxalic acid.

139. Urates.—Uric acid is separated from the blood by the kidneys, in the form of a urate, which is readily soluble in water. After its separation, however, this salt may soon undergo decomposition, and insoluble uric acid will be deposited. In the majority of cases, this decomposition does not take place until after the urine has left the bladder; but sometimes it occurs in the bladder itself. The causes of the precipitation of uric acid are well worthy of attentive study, as they are intimately connected with the formation of uric acid calculi. The quantity of urates in healthy urine is very small, but not unfrequently enough is present to form a very abundant deposit after the urine has been allowed to stand for some time. I propose to describe the characters, and allude to the composition, of these salts, when the subject of urinary deposits is brought under notice.

140. Hippuric Acid ($HO_1C_{18}H\,NO_5$) was first detected in horses' urine by Liebig, and was proved by him to exist in healthy human urine in small quantity—a statement which has been confirmed by Lehmann, and recently by Kühne and Hallwachs. It is not found in the urine of carnivorous animals, but among herbivora it occurs in considerable quantity. It does not exist in large quantity in the urine of calves while sucking, but cows' urine contains as much as 1·3 per cent. Lehmann has detected it in considerable quantity in the urine of the tortoise (*testudo græca*).

Hippuric acid is soluble in about six hundred times its weight of cold water. It is very soluble in hot water, and also in alcohol, but is insoluble in ether. It crystallises very readily in various forms, which are derived from the right rhombic prism (Plate XI., Fig. 58; "*Illustrations of Urine*," Plate IX., Fig. 1). It is very easily decomposed into benzoic acid, especially in the presence of extractive matters, and other constituents of the urine. In testing for this substance, the perfectly fresh urine only should be employed. It is curious that benzoic acid, when taken into the organism, is eliminated in the urine in the form of hippuric acid—a fact which was first made known by Mr. Ure.

It may be prepared by adding milk of lime to fresh cows' urine. The mixture is to be boiled for a few minutes, strained, and exactly neutralised with hydrochloric acid. The solution is next to be boiled down to one-eighth of its original bulk, and considerable excess of hydrochloric acid added, when brown crystals of the acid form. These may be purified by solution in water, through which a current of chlorine is to be transmitted, in order to decolorise the liquid. It may always be readily obtained from human urine after taking ten grains of benzoic acid.

The quantity of hippuric acid is increased when a purely vegetable diet is taken; but it is certain that the whole of the hippuric acid formed in the organism is not derived from this source. The proportion of hippuric acid in human urine was formerly considered to be so small, that it was scarcely possible to make a satisfactory quantitative determination; but Hallwachs has lately shown that as much as *thirty grains* or upwards are excreted in twenty-four hours. Weissmann obtained as much as 34·5 grains from his own urine in the course of twenty-four hours, when he was on a mixed diet.

Very little is known with reference to the formation of hippuric

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acid; and although the subject has been very carefully investigated by Kühne and Hallwachs, who have published two very elaborate memoirs, there still remains much to be discovered. These observers hold that the hippuric acid is produced from the glycocol formed in the liver. Hallwachs is led to conclude, from numerous experiments, that the production of hippuric acid is determined rather by the chemical changes going on in the organism, than by any peculiarities of the food; for, if a purely animal diet was taken, hippuric acid was still found in the urine.* Lehmann found much hippuric acid in the urine of fever patients, and always detected it in diabetic urine.

Robin and Verdeil give drawings of some crystals which they found in the urine of a man aged 30, who took little exercise, but lived on highly nitrogenised diet: and which they considered to be hippuric acid: a statement apparently founded upon the resemblance of these crystals to those produced by the decomposition of hippurate of soda. They do not mention that the crystals were subjected to any chemical examination; and, in the absence of stronger evidence than mere resemblance in form, it seems to me that we are hardly justified in assuming that the crystals were composed of hippuric acid. It is very doubtful if this acid ever crystallises in urine spontaneously.

141. **Extractive Matters.**—Under the head of extractive matters are included certain organic substances which have never been obtained in a state of perfect purity, which are uncrystallisable—not volatile without decomposition—and incapable of being isolated. Chemists have described several kinds of extractive matters characterised by their behaviour with solutions of acetate of lead, bicloride of mercury, tincture of galls, &c. Within the last few years, however, several bodies, formerly included under the indefinite term of extractive matters, have been separated, and their chemical properties accurately determined. As instances, I need only mention albuminate of soda, binoxide and teroxide of protein, creatin and creatinine, hippuric acid, lactic acid and lactates, and certain colouring matters. The extractive matters in urine are entirely excrementitious; but it seems most probable that those present in the blood represent a certain stage of the metamorphosis of some of the constituents of

* An excellent review of these researches will be found in Vol. XIV., p. 156, of the "*Medico-Chirurgical Review.*"

that fluid—either a state intermediate between the nutritive pabulum and the tissue into which it is to be converted (progressive metamorphosis or histogenesis), or a condition resulting from the disintegration of tissue previous to its elimination from the body in the form of urea, creatine, uric acid, &c. (regressive metamorphosis or histolysis). The extractive matters of urine may be divided into three kinds.

142. **Water Extract.**—The first is called water extract, because it is insoluble in absolute alcohol, and in spirit of specific gravity ·833, but is soluble in water. It exists only in small quantity. Infusion of galls and bichloride of mercury produce scarcely any effect upon it, but neutral and basic acetates of lead give copious precipitates.

143. **Spirit Extract.**—The second kind of extractive matter is termed spirit extract, because it is insoluble in absolute alcohol, but soluble in water, and in spirit ·833. It contains much chloride of sodium. The solution of this extract is unaffected by infusion of galls, bichloride of mercury, and neutral acetate of lead; but a bulky precipitate is caused by basic acetate of lead.

144. **Alcohol Extract.**—The alcohol extract is soluble in water, in spirit ·833, and also in absolute alcohol. Its chemical reaction appears to be very similar to the last.

These are the extractive matters which are met with in healthy urine. In certain diseases, however, extractives drain off from the blood, and sometimes in very large quantity, which are not present in a state of health. My friend, Dr. G. O. Rees, many years since showed that this extractive could be detected in morbid urine by adding tincture of galls; and that the proportion varied greatly in different cases. Healthy urine is scarcely affected by tincture of galls, but this blood-extractive is at once precipitated by it. In order to detect it, tincture of galls is to be added to the filtered fluid; and if this extractive is present, a precipitate is *at once* produced. Should the urine contain albumen, this must, in the first instance, be separated by boiling and filtration. It is only the precipitate which *immediately* follows the addition of the tincture of galls that must be noticed. In some cases, the extractive drains away from the blood, without the escape of albumen. ("Lettsomian Lectures," by

G. O. Rees, M.D., F.R.S.; "*Medical Gazette*," 1851.) I shall have occasion to recur again to this interesting subject, when discussing the characters of the urine in disease.

One thousand grains of healthy urine will contain from fifteen to twenty grains of extractive matters. The solid matter contains from 15 to 40 per cent. of these substances. In twenty-four hours, about 200 grains of extractive matters are eliminated in the urine.

The physiological importance of extractive matters is quite unknown, and hitherto no one has been able to ascertain their nature, or discover the part which they play in the animal economy. Their presence in the blood, and in all the animal fluids, as well as in the solid organs and in the excretions, clearly prove them to be substances of great importance; and it must be remembered that, in the urine, the proportion of extractive matter is often greater than that of the urea itself. The amount of extractive matters in the different fluids and secretions of the body is a subject well worthy of investigation, and likely to yield valuable results.

145. Sulphur Compounds.—In certain cases of disease, urine, soon after it is passed, evolves a very powerful odour of sulphuretted hydrogen, probably resulting from the decomposition of substances rich in sulphur. This fact has been observed by many, and I noticed frequently, in examining the urine of insane patients, a piece of paper, anointed with a solution of acetate of lead, soon became blackened from the formation of sulphuret. Considerable quantities of unoxidised sulphur have been obtained even from healthy urine. Ronalds, in five different cases, obtained from 3 to 5 grains of sulphur in the twenty-four hours ("*Philosophical Transactions*," 1847), and Griffiths found 4 grains in healthy urine. These observations are confirmed by Dr. Parkes, and Bischoff and Voit have stated that a large quantity of sulphur is constantly present in the urine of dogs.

146. Sugar.—Brücke has lately again stated that traces of sugar always exist in healthy urine, and his observations have been confirmed by Dr. Bence Jones. ("*Trans. Chem. Soc.*," April, 1861.) This subject will come under notice in a subsequent chapter.

147. Vesical Mucus.—Vesical mucus exists in very small quantity in healthy urine. It forms a faint flocculent cloud, which settles

towards the lower part of the fluid, after the specimen has been allowed to stand for some time (§ 114).

148. Lactic Acid ($2\ HO_1C_{12}H_{10}O_{10}$).—Lactic acid is not constantly present in healthy urine in quantities sufficient to be recognised; but sometimes it is found in the urine of persons who may be considered to be in tolerably good health. Liebig denied its existence in healthy urine altogether; but its presence in this fluid—at least, under certain physiological conditions, as stated many years ago by Berzelius—has been confirmed by Franz Simon, Lehmann, and others; although, on the other hand, it appears nearly certain that the salt assumed to be lactate of zinc by many observers was not really of this nature, but probably consisted of a combination of another acid, which, unlike lactic acid, contains nitrogen.

In order to ascertain the presence of lactic acid, a baryta salt should be first prepared, as Lehmann has recommended, from which a lime salt is easily formed by the addition of sulphate of lime. The lactate of lime crystallises in double brushes, as seen by the microscope. From the lime salt a copper salt is prepared by the addition of sulphate of copper. ("*The Microscope, in its Application to Clinical Medicine,*" 2nd Edition, Figs. 123, 124, p. 123.) This is examined by the microscope. The lactate of copper is decomposed by placing a small bar of zinc in the solution; and upon this, in a short time, crystals of lactate of zinc are deposited, whose angles may be measured in the microscope. ("*The Microscope,*" &c., 2nd Edition, Fig. 125, p. 123.) For the details of this process, I must refer to Lehmann's "*Physiological Chemistry,*" translated by Day, Vol. I., p. 91.

According to some observers, the phosphate of lime and the ammoniaco-magnesian phosphate are held in solution by the lactic acid. They may also be dissolved by the chloride of ammonium, according to Dr. G. O. Rees. MM. Cass and Henry have endeavoured to prove that the lactic acid exists in the form of lactate of urea. Lactates of soda and ammonia are also most probably present in the majority of cases. Lactic acid is occasionally met with in urine, and some other organic acids which are sometimes present are described below.

149. Oxalic Acid ($HO_1C_2O_3$) has been found in healthy urine

by Strahl and Lieberkühn. Böcker estimated the quantity at 1·42 grains in twenty-four hours.

150. Peculiar Organic Acids.—Besides carbonic acid, urine contains, according to the observations of Städeler, a peculiar acid to which the name of *damaluric acid* has been given. It has a powerful odour; but little is yet known of the circumstances under which this volatile acid occurs. *Phenylic* or *carbolic acid*, usually known as *creasote*, has also been detected in urine; but these acids, with the *damolic* and *taurylic acids*, as they occur in urine, have as yet been so little studied, that we know nothing of any practical importance connected with them. Campbell and Lehmann state that urine contains traces of formic acid ($C_2\ H_2\ O_4$).

Although the urea and some other constituents of the urine may be more conveniently and more quickly estimated, by the volumetric process of analysis (Chapter II.), the practitioner is recommended to carry out the following routine plan of analysis. In the course of the examination he will become practically familiar with the chemical and microscopical characters of the most important constituents of the urine. Small quantities of the residues, &c., obtained, should always be submitted to microscopical examination.

Systematic Qualitative or Quantitative Analysis of Healthy Urine.

151. Organic Constituents.—1. In the first place, the reaction and specific gravity of the specimen are to be taken, and any general points noticed. (Lecture I.)

2. Two portions of urine (500 or 1,000 grains) are to be placed in separate porcelain capsules, and evaporated to dryness with the cautions previously given. In the first portion, A, the *organic constituents* are to be estimated; in the second, B, the proportion of *salts* is to be ascertained (Chapter VII., § 183). A, when dry, is to be weighed; and thus the quantity of *water* is obtained. The residue is known to be quite dry when *two successive* weighings exactly correspond. The solid matter is to be treated with successive portions of boiling alcohol, until nothing more is taken up. These are decanted into another basin, or passed through a filter; and the alcoholic solution, containing urea and extractives, is to be evaporated

nearly to dryness—alcohol extract—C; the residue insoluble in alcohol—D.

C. The alcohol extract is to be treated with a few drops of water, and placed over the water-bath. Crystals of oxalic acid are to be added until they are no longer dissolved. It is important to add *excess* of oxalic acid crystals. A drop of the solution may be placed on a glass slide, and the crystals of oxalate which form subjected to microscopical examination (§ 128, Plate XI., Fig 56). The mixture is allowed to cool, and the impure crystals of oxalate of urea and excess of oxalic acid are to be slightly washed with ice-cold water, and pressed between folds of bibulous paper, to absorb the extractive matters. The crystals are to be redissolved in a small quantity of water, placed in a large vessel, and carbonate of lime added until effervescence has entirely ceased. After the mixture has been allowed to stand for some time, it is to be thrown upon a filter.

The solution separated from the oxalate of lime consists of *urea* with a little colouring matter. It is to be carefully evaporated to dryness, and weighed. If the residue is not entirely soluble in alcohol, it contains impurity which must be deducted from the weight of the urea.

Or, the alcohol extract, C, may be treated with a few drops of water, so as to form a thick syrup; and nitric acid added by drops, while the basin which contains the extract is plunged in a freezing mixture. A little of the mixture should be examined in the microscope (Plate XI., Fig. 55). When sufficient nitric acid has been added to combine with all the urea present, the whole is to be allowed to stand for some time; the crystals carefully washed with a very little ice-cold water, and carefully placed on a porous tile, which will absorb the excess of nitric acid and the extractive matters, leaving crystals of *nitrate of urea*, which are to be carefully dried and weighed. By a simple calculation, the quantity of urea is easily ascertained.

D. The residue insoluble in alcohol is to be treated with boiling water and thrown upon a filter. There remain upon the filter, *mucus* from the bladder and other parts of the urinary mucous membrane; *uric acid; phosphate of lime;* and *ammoniaco-magnesian phosphate*, with a mere trace of *silica*. This residue is to be carefully dried and weighed. It is then to be incinerated; and, after the ash has been completely decarbonised, its weight is to be

deducted from that of the residue insoluble in alcohol; and thus the proportion of uric acid and vesical mucus is ascertained. By deducting the united weight of all these different substances—urea, uric acid, mucus, and earthy phosphate—from the solid matter, we calculate the quantity of extractive matter present. According to this plan, we have ascertained the proportion of the following constituents in 500 or 1,000 grains of urine.

Water.................................
Solid Matter.............................
Urea...............................
Extractive matters.....................
Mucus and uric acid...................
Earthy phosphate and silica...............
Fixed salts..........................

Many of the processes above described are imperfect, and likely to give results which are not quite accurate; still the plan is one which is practically useful, and, when a series of results is required, answers very well. In the analysis of animal fluids, it is impossible to attain to perfect accuracy, owing to the changes taking place in the ingredients of the fluid, which are produced by the analytical processes to which they are subjected. Moreover, in such inquiries, it is far more desirable to know the general change which takes place, under various circumstances, in the quantities of the different constituents, than to be acquainted with the exact absolute proportion of each present.

CHAPTER VII.

HEALTHY URINE. III. INORGANIC CONSTITUENTS.—*On the Salts generally—Changes effected in the Composition of the Salts by Incineration—Proportion of the Saline Matter in Urine — Phosphates — Common Phosphate of Soda — Alkaline Phosphate of Soda—Acid Phosphate of Soda—Phosphate of Soda and Ammonia—Phosphate of Magnesia—Phosphate of Ammonia and Magnesia—Phosphate of Lime—Estimation of the Alkaline and Earthy Phosphates—Quantity of Phosphates—Sulphates; Quantity; Estimation—Carbonates—Chloride of Sodium; Quantity; Detection—Circumstances affecting the Excretion of Chloride of Sodium—Bases in Urine—Soda and Potash—Lime—Magnesia—Iron —Silica—Alumina—Systematic Quantitative and Qualitative Examination of the Saline Matter of Healthy Urine.*

INORGANIC CONSTITUENTS OF HEALTHY URINE.

THE saline or inorganic constituents of healthy urine are composed of those substances which remain after the solid matter has been exposed to a red heat, and the carbon burnt off so as to leave a pure white ash. If a little of the solid matter of urine or other animal fluid be placed in a platinum capsule, or upon a piece of platinum foil, which should be very large in proportion to the quantity of solid matter operated on, and exposed to the red heat of a spirit or gas lamp, it will melt and boil up, giving rise to the evolution of offensive gases, which result from the decomposition of the organic constituents. When this has ceased, a charred mass, consisting of carbon and the saline matters indestructible at a red heat, of the urine, remains. After this black spongy mass has been kept in the open capsule, at a dull red heat, for a few hours, the carbon will

gradually disappear, in consequence of the action of the oxygen of the air, which at this temperature combines with it, and forms carbonic acid. A pure white ash, which has an alkaline reaction alone remains; and this consists entirely of saline or inorganic material, which is indestructible at a red heat.

152. Changes effected in the Composition of the Salts by Incineration.—Now, it must not be concluded that the salts which we find in the ash existed in precisely the same state in the urine previous to incineration; for we know that many of these salts, when heated together, undergo mutual decomposition. Some of them may even be volatilised, if kept for a considerable time at a red heat. A mixture of carbonate of soda and chloride of ammonium becomes decomposed at a red heat. Chloride of sodium remains behind, while carbonate of ammonia is evolved. Any lactates, oxalates, and salts, of other organic acids present in the urine, will be found in the ash, in the form of carbonate, although no carbonate existed in the urine originally. The ammoniaco-magnesian or triple phosphate will be found in the ash as phosphate of magnesia; the phosphate of soda and ammonia, as phosphate of soda. Other phosphates also become completely changed by the process of incineration, and by the action of other salts present in the ash upon them. During the incineration, a considerable loss of chlorine also takes place.

Again, unoxidised substances, such as sulphur and phosphorus, and partially oxidised compounds, in combination with organic materials, will become oxidised in the process of decarbonisation; and will, therefore, be found in the ash in the form of sulphuric and phosphoric acid. These will react upon some of the bases present, and sulphates and phosphates will be formed.

Professor Rose, of Berlin, in a beautiful series of experiments, has proved that the mineral constituents exist in very different states in various organic substances. From the *carbonaceous* ash of some organic matters, the greater proportion of the salts can be extracted with water or acids; while, in other cases, but little saline matter can be separated, unless the mass be exposed to the oxidising action of the air for some time. This shows that the substances must have originally existed in an unoxidised or in a partially oxidised state, probably in combination with some organic material.

In certain substances, then, the greater quantity of the mineral material is perfectly oxidised (*teleoxidic*); in others, it exists partly in an oxidised and partly in an unoxidised state (*meroxidic*). Professor Rose was not able to discover any substance in which it occurred completely unoxidised (*anoxidic*). In blood, milk, yolk of egg, and flesh, a considerable portion of the mineral constituents are *meroxidic;* while, in urine and bile, they are almost entirely *teleoxidic:* which is exactly what we should expect, when we consider the different nature and offices of these fluids.

153. Proportion of Saline Matter in Urine.—About one-fourth of the solid matter of healthy urine consists of saline constituents which are not destroyed by a red heat.

One thousand grains of healthy urine, containing from forty to sixty grains of solid matter, will give from ten to fifteen grains of fixed salts. Of the salts, more than nine-tenths are soluble in water (alkaline salts); while the remainder can only be obtained in solution by adding an acid (earthy salts). A mere trace remains behind, which is insoluble in water, acids, and alkalies. This consists of silica, with, perhaps, a little carbon which has resisted oxidation. These numbers are, of course, only approximative, as the amount of salts is liable to great variation.

The saline constituents soluble in water are composed of the following acids and bases:—

Sulphuric acid (and sulphur).	Potash (and potassium).
Phosphoric Acid.	Soda (and sodium).
Hydrochloric acid (chlorine).	

The salts may be readily obtained in a crystalline state by dissolving the residue in hot water, and evaporating a few drops of the solution on a glass slide. The crystals are represented in the "*Illustrations of Urine*," Plate I., Fig. 2.

The mineral constituents insoluble in water are composed of the following acids and bases:—

Phosphoric acid.	Lime.
Carbonic acid (occasionally).	Magnesia.
Silicic acid or silica.	Alumina (sometimes).

In disease, the mineral constituents have been found to vary in quantity quite as much as the organic substances; and other salts are not unfrequently found, which will come under notice at a future

time: while occasionally one or more of the saline compounds mentioned in the above list are altogether absent.

The organic constituents of the urine have hitherto received a greater share of attention than has been given to the inorganic salts; but, from recent investigations, it seems probable that, before long, the physician will regard a departure from the healthy standard in the saline constituents, with as much attention as he has been accustomed to observe an increase or diminution in the quantity of the urea, uric acid, or other organic ingredients.

154. Phosphates.—The phosphates are a very important class of salts, which exist in greater or less quantity in all the tissues of the body, in the secretions, and in considerable proportion in the blood. The salts of phosphoric acid which are carried off from the organism in the urine, may be divided into two classes.

1. The *alkaline phosphates* are *soluble* in water, and are not precipitated from their solutions by ammonia or other alkalies. When ammonia is added to healthy urine, the *alkaline* phosphates are not thrown down. Some of the most important alkaline phosphates are *phosphate of soda*, *acid phosphate of soda*, and *phosphate of soda and ammonia.*

2. The earthy phosphates are *insoluble* in water, but are dissolved by the mineral acids. Most are soluble in organic acids, although they dissolve very slowly if the acids are dilute. They are held in solution even by carbonic acid. Most albuminous substances have the power of dissolving earthy phosphates; and casein holds in solution a considerable quantity of phosphate of lime. The earthy phosphates, as phosphate of lime and phosphate of magnesia, are always precipitated when ammonia is added to healthy urine.

Of the phosphoric acid eliminated in the urine in the form of phosphates, the greater proportion is doubtless taken in the food; but a certain amount is formed in the organism by the oxidation of the phosphorus of albuminous tissues, which takes place during their disintegration. Much of the phosphoric acid formed in the organism is doubtless produced in the nervous tissue.

Phosphoric acid is one of those acids which exist in three forms —the monobasic, bibasic, and tribasic acids, which combine respectively with one, two, or three equivalents of base, to form three different classes of salts.

Tribasic phosphates . . .	$3\ Na\ O,\ PO^5+24\ Aq.$ $2\ Na\ O,\ HO,\ PO^5+24\ Aq.$ $Na\ O,\ 2\ HO,\ PO^5+2\ Aq.$ $Na\ O,\ HO,\ NH^4\ O,\ PO^5+8\ Aq.$
Bibasic or pyrophosphates .	$2\ Na\ O,\ PO^5+10\ Aq.$
Monobasic or metaphosphates	$Na\ O,\ PO^5.$

Now, the phosphates found in the organism are all *tribasic phosphates*, and consist of three equivalents of base, combined with one equivalent of phosphoric acid, with different proportions of water of crystallisation. The elements of the base of a tribasic phosphate may be various. Thus they may consist of three equivalents of soda or other base, or two equivalents of soda and one of water acting the part of a base, or one equivalent of soda and one of ammonia and one of water acting the part of a base, combined with one equivalent of phosphoric acid.

The chemical composition of the phosphates occurring in urine is represented in the following table:—

Common or rhombic phosphate of soda, having an alkaline reaction.	$2\ Na\ O,\ HO,\ PO^5+24\ Aq.$
Acid phosphate of soda, having an acid reaction	$2\ HO,\ Na\ O,\ PO^5+2\ Aq.$
Alkaline phosphate of soda, having a highly alkaline reaction . .	$3\ Na\ O,\ PO^5+24\ Aq.$
Phosphate of potash*	$3\ KO,\ PO^5.$
Phosphate of ammonia and magnesia, ammoniaco-magnesian or triple phosphate	$2\ Mg\ O,\ NH^4O,\ PO^5+12\ Aq.$
Acid phosphate of lime	$2\ Ca\ O,\ HO,\ PO^5+3\ Aq.$
Phosphate of lime (bone-phosphate)	$3\ Ca\ O,\ PO^5.$

Alkaline Phosphates.

155. Common Phosphate of Soda ($2\ Na\ O,\ HO,\ PO^5+24\ Aq$). —This salt exists in healthy urine in the proportion of about two grains in one thousand. The fixed salts contain perhaps from 20 to 30 per cent. of ordinary phosphate of soda. Its presence in healthy urine may be proved by adding absolute alcohol to the syrupy fluid

* It is doubtful if phosphate of potash usually exists in urine, as chloride of sodium and phosphate of potash decompose each other, forming chloride of potassium and phosphate of soda. It is not improbable that it may exist in urine in which the chloride of sodium is present in very small quantity, or altogether absent, as in pneumonia and some other acute diseases.

obtained by evaporating the urine over a water bath. This concentrated fluid is poured off from the salts which have crystallised, and placed in a small glass vessel. The alcohol is added; and, after the mixture has stood for some time, the crystals are deposited upon the sides of the glass. This method is given by Robin and Verdeil. ("*Traité de Chimie Anat. et Physiol.*," par Ch. Robin et F. Verdeil.)

156. Acid Phosphate of Soda ($Na\ O$, $2\ HO$, $PO^5 + 12\ Aq$).—This salt has only been found in the urine; and to it, at least in many cases, the acid reaction of the urine is due. This acid phosphate of soda may be formed from the common phosphate (which has an alkaline reaction), by the addition of uric acid, which removes from the common phosphate one equivalent of soda, forming *urate of soda;* and the reaction of the mixture becomes acid, in consequence of the formation of the *acid phosphate.*

The acid phosphate of soda may be obtained from the concentrated urine treated with absolute alcohol, after the separation of the common phosphate. The acid salt, which is much more soluble, becomes deposited in the course of a few days; but its separation may be expedited by the addition of ether. The phosphate has been separated from the urine by MM. Robin and Verdeil, who attribute the acid reaction of urine to its presence ("*Comptes Rendus. Mém. de la Soc. de Biologie,*" Paris, 1850, p. 25; also "*Traité de Chimie Anat. et Physiol.,*" 1853). The crystals of this salt are figured in Robin and Verdeil's "*Atlas,*" Plate IX., Fig. 2.

157. Alkaline or Basic Phosphate of Soda.—$3\ Na\ O$, $PO^5 + 24\ Aq$.—This phosphate is considered by some to be present in urine; but it is so readily altered by other salts present, that it is impossible to obtain it from the animal fluids in a state of purity. In the presence of carbonic acid, it is decomposed: one equivalent of soda unites with the carbonic acid to form carbonate of soda, and common phosphate of soda is formed, both which salts have an alkaline reaction—$3\ Na, O, PO^5 + CO^2 + HO = 2\ Na\ O, HO, PO^5 + Na\ O, CO^2$.

Liebig has shown that it is not present in healthy urine, as was stated by Heller; and Messrs. Robin and Verdeil do not enumerate this phosphate as one of the constituents of urine: indeed, if this phosphate were formed, it would, in all probability, be at once resolved into salts of a more stable nature.

158. Phosphate of Soda and Ammonia ($Na\ O, NH^4O, HO, PO^5, + 8\ Aq.$)—This salt, although probably not present in perfectly fresh urine, is usually enumerated as one of the phosphates found in the secretion. The crystals of phosphate of soda and ammonia, or microcosmic salt, are beautiful transparent four-sided prisms.

159. Phosphate of Potash ($3\ KO, PO^5$) is probably not present in healthy human urine; but it has been detected by Bossingault in the urine of the pig, in the proportion of 1·02 per 1,000.

Many vegetable tissues contain a large quantity of phosphate of potash; and it is met with in the juice of muscle in considerable quantity.

160. Quantity.—The proportion of alkaline phosphates in the organism varies very greatly according to the nature of the food, amount of exercise, &c. Generally, the proportion is smaller in herbivorous than in carnivorous animals. Muscular fibre contains a large amount of phosphates. Wheat, and the seeds of the cerealia generally, contain a considerable quantity of alkaline phosphates. Robin and Verdeil found, in the ash of the blood of a dog fed upon flesh, as much as 12 per cent. of phosphoric acid, combined with soda and potash; while the ash of the blood of the ox did not contain more than 3 per cent. When the dog was fed upon potatoes, the proportion fell to 9 per cent. The ash of the blood of man contained about 10 per cent. of phosphoric acid. In urine, Berzelius found 2·94 per 1,000; and Simon, from 1·25 in slightly acid urine, to 2·75 in very acid urine.

Breed and Winter estimate the quantity of phosphoric acid removed from the organism in the urine, in the course of twenty-four hours, at from 59·48 to 79·97 grains. The proportion increased considerably after taking food. This quantity corresponds to from 120 to 160 grains of phosphatic salts. Dr. Parkes estimates the phosphoric acid at 48·80 grains in 24 hours.

The quantity of phosphoric acid increases for some hours after a meal. Vogel, Winter, and others have made numerous experiments on this point; and their researches show that the hourly variation in the excretion of phosphate is regular. The morning urine contains the smallest quantity. In some of Dr. Bence Jones's analyses, however, the quantity of alkaline phosphates is even greater in the urine passed before than in that secreted after a meal. ("*Animal Chemistry,*" p. 81.)

The proportion of phosphates in the urine depends much upon the nature of the food. The quantity is increased if phosphorus be taken, proving that this substance does become oxidised in the organism. That the greater proportion of the alkaline phosphates present in the urine are derived from the food is rendered evident by referring to the amount introduced into the organism in this manner. A man taking about fourteen ounces of bread and twelve ounces of meat, with half a pound of potatoes and half a pint of milk, would take about 130 grains of alkaline phosphates.* As we have seen, he would eliminate, in his urine, about the same quantity. These numbers are only to be regarded as rough approximations to the truth; but I think, at present, it must be admitted that the quantity of phosphate excreted in the urine, and formed in the organism, is so small in comparison to that derived from the food, of which the amount is liable to great variation, that, in the present state of animal chemistry, it is quite impossible to form an estimate of the amount derived from the former source, or to separate this from the phosphates taken in the ingesta.

Still it is certain that some of the phosphoric acid is formed within the organism, by the oxidation of the phosphorus of the albuminous tissues; but this must bear but a small proportion to the whole amount of phosphate removed in the urine, as the above data conclusively show.

The fluid which surrounds the elementary fibres of muscle has an acid reaction, depending probably upon the presence of acid phosphate of soda, produced by the action of lactic or some other organic acid upon phosphate of soda. Du Bois Raymond has, however, shown that this acid reaction is not met with when the muscles are at rest. Recent experiments have shown that the amount of disintegration taking place in muscular tissue during its activity is much less than was supposed. It is probable that very much of the material generally ascribed to the disintegration of the muscle is really due to the chemical changes produced in the nerves ramifying on the surface of the elementary fibres. The ashes of most tissues contain phosphates

* 14 oz. of bread	contain	53·2 grs.	of phosphates.
12 oz. of beef	"	40·7 "	"
½ lb. of potatoes	"	11·0 "	"
½ pint of milk	"	32·0 "	"
		136·9 grs.	of mixed phosphates.

in large proportion; and Schmidt has shown that a considerable quantity of phosphate is always present in young tissues. The quantity of alkaline phosphate required by the organism is considerable; for, besides the large proportion which is excreted in the urine, the ash of the solid excrements contains as much as 20 per cent. alone. The phosphoric acid required is, no doubt, supplied principally by the food, partly in the form of phosphatic salts, partly as phosphorus which is oxidised in the organism. We shall recur to this subject when we have to consider the elimination of the phosphates in disease.

Earthy Phosphates.

The earthy phosphates met with in the urine are—1, the *ammoniaco-magnesian phosphate*, also termed *triple phosphate*, or *phosphate of ammonia and magnesia;* 2, *Basic phosphate of ammonia and magnesia;* 3, *Phosphate of Magnesia.*

These earthy phosphates occur in very small quantity in urine. The secretion in health contains not more than from 1 to 1·5 part in 1,000, and the solid matter contains from 1·5 to 2 per cent. The quantity present in different cases undergoes but slight variation, and seems to be determined, to a great extent, independently of the chemical changes going on in the body. Most of the solids and fluids of the organism contain small quantities of the earthy phosphates. The amount depends, in great measure, upon the quantity of alkaline earths present. Ktetzinsky has shown that in urine there are two parts of phosphate of lime to one part of phosphate of magnesia.

In healthy urine, these earthy phosphates are held in solution, in all probability, by the free acid of the urine, and in some measure by the acid phosphate of soda. The chloride of ammonium present may also contribute to maintain the earthy phosphates in solution in the urine (Dr. G. O. Rees). Very slight changes are sufficient to cause the precipitation of the ammoniaco-magnesian phosphate; and beautiful crystals of this salt are sometimes formed in urine which has a decidedly acid reaction.

It is important to distinguish between *excess* of phosphates in the urine and a *deposit* of earthy phosphate; for a large quantity of earthy phosphate in the urine may pass unnoticed by the practitioner, because it is in a state of *solution;* while a smaller quantity in an *insoluble* state, and therefore very conspicuous, is likely to

receive from him a larger share of attention than its slight importance demands.

161. Precipitation of Earthy Phosphates by Heat.—It is very important to bear in mind that the earthy phosphates are precipitated from some specimens of urine by heat. This precipitate closely resembles that which is produced, in many specimens of albuminous urine, upon the application of heat. It is, however, at once distinguished from albumen by the addition of a few drops of nitric acid, which instantly dissolves the phosphate, while albumen is unaffected by it. Such a mistake has many times been made; and I need hardly say how important it is to avoid the possibility of such an error, as it may lead the practitioner to form an unfavourable prognosis in a case in which there is really no cause whatever for anxiety. The cause of this occasional precipitation of earthy phosphate is obscure. By Dr. Rees it is attributed to an excess of the phosphates being held in solution by chloride of ammonium. Dr. Brett considers that in these cases it is dissolved by carbonic acid; while Dr. Bence Jones attributes this precipitation to the excess of free acid of the urine being neutralised by an alkali, or by common phosphate of soda.

162. Phosphate of Lime ($3\ CaO,\ PO^5$) exists in healthy urine dissolved in acids, in certain salts, or in organic matters. Phosphate of lime is soluble in a solution of carbonic acid, in bicarbonates, and in chloride of ammonium. Albumen and fibrine always retain a certain quantity, and casein holds a large amount in solution. It is found in almost all the tissues, and, when separated, usually occurs in an amorphous state. In urine it sometimes crystallises. The ash of urine contains between 2 and 3 per cent. of this phosphate, and that of excrements upwards of 12 per cent. It may be obtained in quantity from bones.

163. Acid Phosphate of Lime ($2\ CaO,\ HO,\ PO^5 + 3\ HO$.—The existence of this phosphate in urine constantly, is questionable; but, as before remarked, the composition of the phosphates is constantly altering; and an acid phosphate of lime is readily formed by the action of an organic acid on the neutral phosphate of lime.

164. Phosphate of Ammonia and Magnesia, Triple, or

Ammoniaco-Magnesian, Phosphate ($NH^4O, 2MgO, PO^5+12HO$).—The presence of this salt, which is frequently met with in the animal fluids, usually depends upon decomposition having commenced, in which case the ammonia set free combines with the phosphate of magnesia to form the triple phosphate. At the same time there can be no doubt that crystals of triple phosphate are sometimes found in acid urine—not merely forming a pellicle which alone is alkaline, while the fluid beneath retains its acidity (Thudichum)—but as a distinct deposit, leaving a clear supernatant fluid. Lehmann and other observers doubt the correctness of this observation; but the fact has been observed in this country several times, and I have noticed it myself more than once or twice. It is quite possible that the acid reaction may depend upon chloride of ammonium, or some other salt which reddens litmus, and not upon the existence of free acid.

Crystals of triple phosphate are slightly soluble in pure water, but are rendered quite insoluble by a trace of ammonia and ammoniacal salts. They give beautiful colours when examined with a ray of polarised light.

165. Phosphate of Magnesia ($3MgO, PO^5+7Aq.$)—This phosphate is found in considerable quantity in the urine of certain herbivorous animals, and it appears to be a constituent of certain urinary calculi. It is doubtful if it is often present in human urine; but Robin and Verdeil have discovered it in several organs, and also in morbid products. In animal fluids generally, the phosphate of magnesia combines with ammonia, forming the salt which has just been described. When discussing the deposits of phosphates, I shall have to revert to this subject.

166. Microscopical Characters of the Earthy Phosphates.—The phosphate of lime is usually deposited from urine in an amorphous form. Under the microscope, even when the highest powers are employed, the deposit when first formed is found to consist of minute granules. ("*Illustrations,*" Plate XXI., Fig. 4.) Occasionally it occurs as round or oval particles of a high refractive power. Sometimes two of these small particles are connected together, and produce a crystal of the dumb-bell form. They vary much in size, but are usually very small.

After some time has elapsed, the amorphous granular deposit of phosphate of lime assumes a crystalline form. Dr. Hassall has found

that the crystals formerly regarded as a rare form of triple phosphate are really composed of phosphate of lime. Dr. Bence Jones has also obtained crystals of phosphate of lime from urine by adding chloride of calcium, and Dr. Roberts has written a paper on the same subject. I have found that beautiful crystals of phosphate of lime can always be obtained by allowing solutions of phosphate of soda and chloride of calcium in glycerine gradually to mix together. In this manner very perfect crystals may be produced. Many days may elapse before large crystals are found.

The *phosphates of magnesia* crystallise in several different forms, which seem to be determined by slight changes in circumstances. The first is the stellate form, which occurs when ammonia is added to healthy human urine. The crystal consists of from four to five feathery rays, with a minute oval mass situated at the origin of each ray from the centre. These crystals gradually assume the more common form of the triple phosphate: secondly, that of a beautiful triangular prism, with obliquely truncated extremities. Great variation, however, is observed in the form of these crystals; sometimes they appear almost square; and frequently they might be mistaken for octohedra, in consequence of the approximation of the obliquely truncated ends, and the shortening of the intermediate portion of the crystal. Prisms or knife-rest crystals of triple phosphate are represented in Plate XII., Fig. 62. The feathery crystals of triple phosphate are represented in the "*Illustrations*," Plate IX., Fig. 2. After standing for some time, the rays alter in shape, and gradually little triangular crystals begin to make their appearance, as represented at *a*. After the lapse of some days, they are entirely converted into the ordinary triangular crystals. ("*Illustrations*," Plate IX., Fig. 1.; Plate XXI., Figs. 1, 3; Plate XXIII., Fig. 1). Other forms of triple phosphate are described in the chapter on *urinary deposits*.

167. Estimation of the Earthy and Alkaline Phosphates.—The earthy phosphates (*phosphate of lime* and *phosphate of magnesia*) are easily detected by ammonia. If a few drops of solution of ammonia are added to a specimen of healthy urine, a turbidity is soon observed, owing to the precipitation of phosphate of lime in an amorphous form, and triple or ammoniaco-magnesian phosphate in flocculent snow-like crystals, which increase in size for some time

after their first precipitation. Stirring favours the separation of the phosphates; but the form of the crystals must, of course, be studied in a mixture which has been allowed to remain quiet. If it is required to estimate the proportion of these earthy phosphates, it is only necessary to separate them by filtration, ignite in a platinum capsule, and weigh the ash.

168. Alkaline Phosphates.—The phosphoric acid combined with the alkalies may be precipitated from the fluid filtered from the earthy phosphates by the addition of a salt of lime or magnesia, when an insoluble deposit, composed of phosphate of lime or phosphate of ammonia and magnesia, is produced. If it is desired to ascertain the quantity of alkaline phosphates, it is only necessary to filter the precipitate, dry, ignite, and weigh it. From the phosphate of lime or phosphate of magnesia it is easy to calculate the proportion of phosphoric acid present; but, for ordinary purposes, it is enough to consider the weight as corresponding to the quantity of alkaline phosphates present in the urine, there being but slight difference in the equivalent numbers of the salts. The volumetric method of estimation, in which the phosphate is precipitated by a persalt of iron, has been described in Chapter II. Nitrate of silver produces in urine a yellow precipitate of tribasic phosphate of silver, which is soluble both in excess of ammonia and also in nitric acid. Upon adding a few drops of the former to the yellow deposit in this test-tube, it instantly dissolves. If nitric acid just sufficient to neutralise the ammonia present be added, the yellow precipitate reappears; but, when one drop more falls in, it is immediately redissolved. This might be repeated many times. The precipitate of *chloride* of silver is quite *insoluble* in nitric acid, although soluble in ammonia; so that, in testing for chloride of sodium in urine, it is always important to add a few drops of nitric acid, to prevent the precipitation of the phosphate of silver.

169. Sulphates.—Unlike the phosphates, the sulphates are present in very small quantities in the fluids of the body generally. The urine, however, contains a large quantity. This class of salts is not present in the milk, bile, or gastric juice. The blood contains only ·20 per 1,000; while, in healthy urine, sulphates exist in the proportion of from 3 to 7 parts per 1,000.

The proportion of sulphates undergoes a considerable increase

after violent exercise, and under the influence of a purely animal diet—conditions under which the urea suffers a considerable augmentation. In fact, in all those conditions which are associated with an increased formation of urea, a large proportion of sulphates will also be observed. It would appear that the oxygen, hydrogen, carbon, and nitrogen of the albuminous substances, are eliminated in the form of urea; while the sulphur is removed in the state of sulphuric acid.

Dr. Bence Jones's experiments have shown that both vegetable and animal food increase the proportion of sulphates in the urine. When sulphuric acid, sulphur, or sulphates, are taken internally, the amount of these salts is augmented. These facts prove that the sulphates found in the urine are in great part formed during the disintegration of tissues. They must be regarded as excrementitious, and are probably not concerned in nutrition.

The sulphuric acid eliminated in the urine occurs in the form of sulphate of potash and soda.

The urine contains about 3·5 grains per 1,000 of sulphate of potash, and about 3·0 grains of sulphate of soda. About thirty grains of sulphuric acid, corresponding to about fifty-seven grains of the mixed sulphates, are excreted by a healthy man in twenty-four hours.

The sulphates present in the urine are all soluble, like the alkaline phosphates; and, in order to prove their presence in a fluid, it is necessary to add some salt, the base of which forms an insoluble precipitate with sulphuric acid. Baryta salts are the most convenient for this purpose. Either the nitrate of baryta or the chloride of barium may be employed. In testing for sulphates in urine, it is necessary to add a little free nitric or hydrochloric acid previous to the addition of the baryta salt, in order to prevent the precipitation of a *phosphate* as well as a *sulphate* of baryta. The former is very soluble in free acid; the latter quite insoluble. If the quantity of sulphate is to be estimated, it is necessary to boil the mixture, or to drop the baryta salt into the boiling solution; otherwise the pre-precipitated sulphate of baryta will pass through the pores of the filter. The phosphoric acid may be estimated in the clear fluid which passes through the filter by the addition of ammonia, which throws down phosphate of baryta. The contact of the air must, in this case, be avoided.

170. Sulphate of Lime has not been detected in human urine, but it has been found in that of animals, and is a constituent of some urinary calculi. I have seen crystals of sulphate of lime in the uriniferous tubes; and it is probable that it may be present in the urine, in some cases, in appreciable quantity. Traces of sulphate of lime are found in the blood. It is found in the pancreatic juice which has been kept for a few hours in a warm place, so that decomposition of some of the organic materials may take place.

171. Carbonates.—Carbonate of soda is not usually reckoned as a constituent of healthy urine, as its presence is entirely dependent upon the kind of food which the person has taken. For instance, carbonate of soda will often be found in the urine after large quantities of fruit have been eaten, in consequence of the salts of the vegetable acids becoming converted into carbonates during their passage through the organism. In the urine of herbivorous animals, alkaline carbonates are found; and frequently the carbonate of lime is also present. In the urine of rodents, these salts, particularly the latter, are abundant. Moreover, carbonate of soda may actually have been present in the urine, although it cannot be detected in the ash; for, if common phosphate of soda be heated with carbonate of soda, the carbonic acid is expelled, and the tribasic phosphate of soda remains. Hence the absence of carbonate from the ash of urine is not always a positive proof that the fluid did not contain lactates before it was subjected to chemical operations. On the other hand, a carbonate may be detected in the ash, although none was present in the urine, in consequence of the decomposition of oxalates and lactates during incineration.

172. Testing for Carbonate.—The presence of carbonic acid is very easily recognised, by the effervescence set up, immediately a little dilute acid is added to the ash. The best plan to test for carbonate in the ash is the following. A small portion of the dry ash is placed on a glass slide, and covered lightly with an ordinary square of thin glass. A drop of acid is then allowed to fall on the glass, so that it will gradually pass between the glasses by capillary attraction, and come into contact with the salt. If any bubbles of gas escape in consequence of the action of the acid, they will be confined beneath the thin glass, and one cannot fail to see them. If they be very

small, the specimens may be subjected to microscopical examination. In this manner, the slightest trace of carbonic acid can hardly escape notice.

If the quantity of carbonate is to be estimated, the ash must be placed in a little apparatus, from which the gas is conducted by a tube into another vessel containing lime or baryta water; or it may be caused to pass through the potash apparatus used in organic analysis. From the weight of the carbonate, that of the carbonic acid is easily calculated. In the last case, its weight is obtained directly.

173. Chloride of Sodium ($NaCl$).—Common salt is always present in healthy urine, although the proportion is liable to great variation, owing to the circumstance that the chloride of sodium is always derived from the food. The importance of this substance to the organism is sufficiently proved by the fact that all kinds of food contain a certain quantity, and almost every specimen of water holds some proportion in solution. Again, it is well known that the health of animals deprived of the proper amount of salt, deteriorates. It is to be detected in nearly all the tissues of the animal body, and is found in large quantity wherever cell-development is actively going on. This is true both with regard to healthy tissues and morbid growths. Common salt crystallises in cubes; but, in the presence of urea and some other organic substances, it assumes the form of a regular octohedron. As is well known, it is readily soluble in water (31·84 parts in 100), diffuses itself rapidly through a large bulk of fluid, and, in a dilute state, permeates tissues with great facility.

Besides common salt, urine also contains a certain quantity of chloride of potassium.

174. Quantity.—Healthy urine contains from three to eight grains of chloride of sodium in 1,000; the solid matter, about 6 per cent.; and the fixed salts, about 25 per cent. or more. Under ordinary circumstances, from 100 to 300 grains of salt are removed from the body in twenty-four hours; but the proportion is influenced by a great variety of circumstances, and is especially effected by the quantity of fluids taken. Dr. Parkes estimates the quantity of *chlorine* at from 92 to 124 grains in twenty-four hours. The amount is very variable in different individuals, according to the proportion

of salt taken with the food. The secretion of chloride of sodium, as would be supposed, attains its maximum a few hours after a meal, and but little is eliminated during the night.

175. Detection.—Chloride of sodium is very easily detected in urine. It is only necessary to acidulate the specimen with a few drops of nitric acid, and then add nitrate of silver. The white precipitate of chloride of silver is quite insoluble in nitric acid, but soluble in ammonia. In order to make a quantitative determination, the chloride of silver is to be dried; and it should be burnt and fused in a *porcelain* capsule before being weighed. The volumetric process, however, is the most accurate (§ 40).

176. Circumstances affecting the Excretion of Salt.—Chloride of sodium is not formed in the organism, but seems to exert some important and beneficial effects during its passage through the tissues; and whenever the nutritive changes are very active, there seems to be an unusual demand for chloride of sodium. But the precise part which the substance plays is at present unknown. The quantity of salt excreted in the urine undergoes great changes in certain diseases. The proportion also varies considerably from day to day, under the influence of an ordinary diet in health; and the ingestion of large quantities of water causes the elimination of a greatly increased amount of common salt. Thus, in one experiment, continued for four days, the following results were obtained: during the first three days, about thirty-six ounces of urine were passed per diem; the specific gravity varied from 1,015 to 1,024. The total quantity of solid matter passed in twenty-four hours was about 750 grains, and the chloride of sodium amounted to 113 grains. On the fourth day a large quantity of water was taken; 258½ ounces of urine, of specific gravity 1,003, were passed; containing a total of 1134·48 grains of solids, and 232·8 grains of chloride of sodium. The phosphoric acid was diminished, and the sulphuric acid was increased by upwards of one-third.

177. Soda and Potash (NaO & KO).—In healthy urine but a very small quantity of potassium is present in the form of chloride; but of soda salts there is a large proportion. The potash salts, as was first pointed out by Liebig, are found in considerable quantities in the muscles, while the soda salts predominate in the blood. Although

phosphate of potash be taken in the food, the corresponding soda salt, which is necessary to the blood, is still found in that fluid; and there can be no doubt that, in the organism, the chloride of sodium is decomposed by the phosphate of potash—a phosphate of soda and a chloride of potassium being formed.

To separate the sodium from the potassium in urine, a somewhat tedious analysis, of which I will just give a rough outline, is necessary. After destroying the organic matter by ignition, the whole of the phosphoric and sulphuric acids are removed, and the potassium and sodium converted into chlorides. A solution of bichloride of platinum is then added, and a chloride of potassium and platinum, and a chloride of sodium and platinum are formed. The potassium salt is most insoluble, and separates in the form of small octohedra, which do not polarize light. These may be separated by filtration. The sodium salt remains in solution, and may be obtained in the form of crystalline needles by concentrating the solution. These crystals exhibit the most beautiful colours when a ray of polarized light is transmitted through them.

178. **Lime** (**CaO**) may be detected in urine by dissolving the salts in acetic acid, and adding a little oxalate of ammonia to the filtered solution. Oxalate of lime is precipitated as a white, granular powder, which passes through the pores of a filter, unless the mixture be boiled previous to filtration. As already mentioned, lime occurs in urine as a phosphate, and occasionally as a carbonate. It forms a urinary calculus very rarely met with in man; but not uncommon in some herbivorous animals. The urine of the horse always contains a number of spherical masses, composed of carbonate of lime, which may be regarded as microscopic calculi. It has been proved by Mr. Rainey that the spherical form which crystalline matter sometimes assumes, depends upon the presence of viscid matter in the solution which contains the crystalline matter. These spherical crystals of carbonate of lime, so constantly found in horse's urine, may be exactly imitated by causing carbonate of lime to crystalize artificially from gum water or other viscid fluids. ("*The mode of formation of shells*," &c.)

179. **Magnesia** (**MgO**) must be precipitated as Ammoniaco-magnesian phosphate, from a concentrated solution of the salts after the

separation of the lime. The fluid should be evaporated to a small bulk, and when quite cold a little of the solution of phosphate of soda should be added to the mixture, rendered alkaline by the previous addition of ammonia. Unless there be already a sufficient quantity of ammoniacal salt in the mixture, some muriate of ammonia should be added, as the magnesian salt is slightly soluble in pure water, but insoluble in solutions of ammoniacal salts.

The solution should be stirred in all cases, for by this means a precipitate can often be produced, although before not the slightest turbidity was observable.

180. Iron (Fe).—Traces of iron may be detected in healthy urine if a large quantity of the secretion be operated upon. Like many other mineral substances, iron passes off in small quantities in the urine, and is generally found in the urine of persons taking preparations of iron. Dr. Harley has shown that iron is a constituent of one of the colouring matters of the urine. (*Uræmatine.*)

181. Silica (SiO_3).—Berzelius, many years ago, demonstrated the presence of *silicic acid*, or silica, in urine. Mere traces are met with in the ash after the removal of the salts insoluble in water, by the addition of strong nitric acid. The silica remains undissolved. This substance is derived principally from wheat, which, like other plants belonging to the cerealia, contains a considerable proportion of silica. Silica has been occasionally met with in urinary calculi, in appreciable quantity.

182. Alumina (Al_2O_3).—It has been stated by authorities that this substance does not pass off from the system in the urine at all; but from several observations which I made some years since, and which I have lately repeated, I have been led to conclude that it is very commonly present in the ash of urine. The alumina detected in the urine is in great part, if not entirely, derived from the alum taken in the bread. Some time since, while in the habit of eating pure home-made bread, I was unable to detect the presence of this substance in the manner presently to be described; but afterwards, when my diet consisted of baker's bread, I found very decided indications of its presence.

The test which has been employed is the ordinary blow-pipe test. A little of the fixed saline residue, which has been perfectly decar-

bonised, is moistened with a solution of nitrate of cobalt, and heated gradually in the blow-pipe flame to a bright red heat. If alumina be present, the bead, upon cooling, is found to be of a beautiful *bright blue* colour. As is well known, there is great difficulty in separating phosphate of alumina from phosphate of lime; and the ordinary process of analysis is not sufficiently delicate to detect this substance in the small quantity in which it ordinarily occurs in the ash of urine. When the ash contains as much as one-fiftieth part, however, I have been able to detect it by the liquid tests. The blow-pipe test above referred to is not without objection, inasmuch as any bead containing phosphates exhibits a blue colour when heated in the blow-pipe with nitrate of cobalt. The blue colour produced is certainly very different to that developed when alumina is present. A bead consisting of phosphates of soda, lime, and magnesia, gave a very dull grayish blue colour with the cobalt; but, when the slightest trace of alumina was added, a very bright and decided colour resulted. I have applied this test, therefore, to the urine salts before and after alum was taken in the food. In the first case, the blue tint was very undecided, or was not at all manifested; while in the last it was bright and distinct.

At a time when I was taking home-made bread perfectly free from alum, I examined the urine. The ash was tested for alumina with nitrate of cobalt in the usual manner, but only a faint blue colour was produced. Immediately after evacuating the bladder (12 noon), five grains of alum were taken, dissolved in an ounce and a half of distilled water. At 6 p.m., about fifteen ounces of urine were passed. A portion of this was evaporated to dryness, and the residue incinerated and decarbonised. A small quantity of the ash was treated with nitrate of cobalt, and heated in the blow-pipe flame. The bead, on cooling, was of a very bright blue colour. This experiment was repeated, with the same result. A similar reaction is met with in a great many specimens of ash obtained from the urine of hospital patients. Although this is not a perfectly accurate test, it indicates the presence of alumina in some specimens of urine in which one would expect a salt of this base to be present; while in urine which was perfectly free from alumina, no indication of its presence was afforded by the test. I think, therefore, if the cobalt test be employed carefully, it is worthy of more trust than most chemists seem disposed to place in it. A further series of researches

is required to prove the proportion of alumina removed in the urine to that which escapes by the intestinal canal, when salts of this base are taken with the food. But I think there can be little doubt that a certain amount of this substance is really carried off in the urine. The urine salts of most persons give a very decided reaction indicating the presence of this substance, a considerable quantity of which is taken with many kinds of bread. Although there are many objections to mixing alum with the bread, and the practice ought clearly to be put an end to, I am not aware that any deleterious effects have been produced by its introduction. Some have attributed habitual constipation to this cause.

It is desirable that the student should be acquainted with the principal characters of the most important inorganic salts of urine; and it has been considered desirable to give the following short course of systematic analysis. When it is required to estimate the proportion of chlorides, phosphates, or sulphates, quantitatively, the volumetric process will, however, be found the most accurate as well as the most expeditious.

Systematic Qualitative or Quantitative Analysis of Healthy Urine: Inorganic Constituents.

183. Analysis.—The portion of urine B, (p. 104), is also to be evaporated to dryness, and the dry residue incinerated in a large platinum capsule, and maintained at a dull red heat until it is perfectly decarbonised and nothing remains but an almost perfectly white ash. This, consisting of the fixed salts, is now to be examined as follows. Boiling distilled water is to be poured upon the saline residue, and the mixture thrown upon a filter.

The *solution* contains the *alkaline salts.*

The *insoluble matter*, consisting of *phosphate of lime, phosphate of magnesia*, and *silica,* remains behind on the *filter.*

1. The residue *insoluble in water* is to be treated with nitric acid, and boiled if necessary. *Silica* remains undissolved. If effervescence occur upon the addition of the acid, *carbonate of lime* was present in the ash. Filter; add excess of ammonia to the filtered solution, and redissolve the precipitated phosphates by adding excess of acetic acid. Next precipitate the lime as oxalate, by the addition of oxalate of ammonia. If the *quantity* of lime is required, the

oxalate must be heated, exposed to the action of a dull red heat in a platinum capsule, and weighed as carbonate.

After the separation of the oxalate of lime by filtration, concentrate the clear solution by evaporation, and add a little ammonia and chloride of ammonium. Stir the mixture, and set it aside, that crystals of *triple or ammoniaco-magnesian phosphate* may form.

2. The *original solution*, containing the urinary salts, soluble in water, is divided into two portions, 2 *a*, 2 *b*.

2 *a*. The first portion is acidified with nitric acid, and treated with *nitrate of silver*. *Chloride of silver*, indicating the presence of chlorine, is precipitated. The chlorine originally existed in combination principally with sodium.

2 *b*. The second portion is also to be acidified with nitric acid, and an excess of solution of nitrate of barytes added; a precipitate of *sulphate of barytes*, proving the presence of sulphuric acid, occurs.

The mixture is boiled and filtered; and, upon the addition of ammonia to the solution, *phosphate of baryta*, showing the presence of phosphoric acid, is precipitated, care being taken to prevent the formation of carbonate of baryta by exposure to the air.

Next the phosphate of baryta is to be separated by filtration; and the solution, which contains nitrate of barytes, ammonia, and the fixed alkalies, is to be concentrated. Excess of carbonate of ammonia and ammonia is to be added, and the mixture thrown upon a filter. The solution is to be concentrated by evaporation, and the barytes separated by sulphuric acid, after which the solution is to be evaporated to dryness, and the residue heated to redness in a hard glass tube, in the mouth of which a fragment of carbonate of ammonia has been placed. The residue is to be treated with water, and filtered. The solution contains the salts of the alkalies, *potash* and *soda*. The former is thrown down in the form of minute octohedral crystals of the *potassio-chloride of platinum*, upon the addition of a solution of bichloride of platinum. After stirring, these may be filtered off.

The solution contains the *sodio-chloride of platinum*. It is to be concentrated, in order that the beautiful acicular crystals of this substance may form.

The presence of the following substances in the specimen of urine submitted to examination, has been proved:

Fixed Salts..........................
Lime ....
Magnesia ....
Potash..........................
Soda ....
Chlorine ....
Phosphoric Acid ....
Sulphuric Acid ....

The constituents not included in the above list, and in that on p. 106, require special processes for their demonstration; and, as many of them exist in very minute quantity, it is not desirable that the student should attempt to test for them in the small amount of urine usually operated upon. The substances alluded to are the following:—

Creatine.	Ammonia.
Creatinine.	Hippuric Acid.
Sarkine.	Iron.
Uræmatine.	Alumina.*
Uroxanthine.	Carbonic Acid.
Phenylic Acid } ?	Leucine } †
Damaluric Acid } ?	Tyrosine } †
Traces of Sugar. ?	

The characters of several of these have already been discussed, and the methods for separating them from the urine described.

* Not necessarily present in healthy urine.

† In urine in certain diseases. Probably not in healthy urine.

CHAPTER VIII.

COMPOSITION OF HEALTHY URINE, AND THE QUANTITY OF THE DIFFERENT CONSTITUENTS EXCRETED IN TWENTY-FOUR HOURS.—*Analyses of Healthy Urine—Total Quantity in twenty-four hours—Quantity in proportion to a given weight of the body—Variation in Quantity at different ages—Average Composition of Healthy Urine—Observations on estimating the Excrementitious Matters—Weighing Machines.*

184. Average Composition of Healthy Urine.—It is clearly very important that we should form a general idea of the quantitative composition of healthy urine, and the amount of the various constituents which are excreted from the healthy organism in twenty-four hours. Those who are making observations on the urine in disease, should be acquainted also with the relative proportion of these different substances to each other. It is true that the healthy variations are very great; but, in certain cases of disease, the difference in the quantity is so considerable that the observer cannot fail to be struck with the importance of the fact. Thus, in health, from 400 to 500 grains of urea are excreted in twenty-four hours. In certain cases of kidney-disease, when the cortical portion is impaired in structure, not more than 100 grains are eliminated; while, in some cases of fever, upwards of 1,000 grains have been removed in the same time. Of the significance of such facts there can be no question; and the physician cannot fail to reflect upon the very different chemical conditions under which life is being carried on in these cases. Without considering all the circumstances likely to affect these abnormal processes, how can we

hope ever to gain that insight into the nature of disease which, in many instances, can alone enable us to modify or counteract the morbid changes going on?

185. Analysis of Healthy Urine.—The composition of healthy urine is given in analyses by Berzelius, Lehmann, and Dr. Miller.

A is an analysis of 1,000 parts of healthy urine by Berzelius; B is one by C. G. Lehmann.

	A		B	
Water	933·00		932·019	
Solid matter	67·00	100·0	67·981	100·0
Urea	30·10	44·9	32·909	48·4
Uric acid	1·00	1·4	1·098	1·5
Lactic acid	17·14 (Lactic acid, Lactates, Water extract, Spirit and alcohol extract)	25·5	1·513	2·3
Lactates			1·732	2·6
Water extract			·632	1·0
Spirit and alcohol extract			10·872	16·0
Chloride of sodium	4·45	6·6	3·712 (Chloride of sodium, Chloride of ammonium)	5·5
Chloride of ammonium	1·50	2·2		
Alkaline sulphates	6·87	10·2	7·321	10·8
Phosphate of soda	2·94	4·3	3·989	5·9
Biphosphate of ammonia	1·65	2·4		
Phosphates of lime and magnesia	1·00	1·4	1·108	1·7
Mucus	·32	·4	·110	·3
Silica	·03	·04		

The following is an analysis of healthy urine by my friend Dr. W. A. Miller, of King's College:—

Specific gravity		1,020	
Water		956·80	
Solid matter		43·2	100·00
Organic 29·79	Urea	14·23	33·00
	Uric acid	·37	·86
	Alcohol extract	12·53	29·03
	Water extract	2·50	5·80
	Mucus	·16	·37
Fixed salts, 13·35	Chloride of sodium	7·22	16·73
	Phosphoric acid	2·12	4·91
	Sulphuric acid	1·70	3·94
	Lime	·21	·49
	Magnesia	·12	·28
	Potash	1·93	4·47
	Soda	·05	·12

186. Total Quantity of Substances excreted in Twenty-four Hours.—But it is most important to be acquainted with the total quantity of the different ingredients excreted in twenty-four hours.

The urine passed during the entire period of twenty-four hours should be collected and measured. From the results obtained, by analysing a portion of this, the total quantity of the different ingredients in the whole amount passed is easily calculated. The quantities of the different substances excreted in twenty-four hours, is stated under their proper heads, and a rough approximation of each is given in the table on p. 136.

Vogel gives the following estimate of the quantity of urine and its most important constituents excreted in twenty-four hours in a state of health:—

Average quantity in twenty-four hours	52¾ to 56 oz.
Average specific gravity	1·020
Average quantity of urea	556 grains.
Average quantity of chlorine	154 "
Average quantity of free acid	33 "
Average quantity of phosphoric acid	66·7 "
Average quantity of sulphuric acid	30·88 "

187. Proportion excreted for each pound weight of the Body.— The relation of the quantity of urinary constituents excreted, to the weight of the body, is also a most important inquiry, and is generally stated at so much for each pound weight.

The following results, taken from Dr. Parkes, give the quantity of urinary constituents excreted for each pound weight of the body in twenty-four hours, adopting 145 lbs. as the average weight of all the men whose urine had been analysed.

Water	158·639 grains.
Urea	3·530 "
Uric Acid	·059 "
Creatine	·032 "
Creatinine	·048 "
Pigment and Extractives	1·062 "
Sulphuric Acid	·214 "
Phosphoric Acid	·336 "
Chlorine	·875 "

The table below is taken from a valuable paper by the Rev. S. Haughton, in the "*Dublin Quarterly Journal*," October, 1862. The results accord very closely with those just given.

	Excreted in 24 Hours.	Excreted in 24 Hours per pound of the body Weight.
Urine	23021·25 grains.	155·348 grains.
Water	22063·44 „	148·881 „
Solid Matter	957·81 „	6·467 „
Urea	493·19 „	3·331 „
Uric Acid	3·15 „	0·021 „
Phosphoric Acid	32·36 „	0·218 „
Sulphuric Acid	31·55 „	0·214 „
Chlorine	106·56 „	0·673 „
Extractives	175·27 „	1·183 „
Balance (viz. inorganic bases)	115·73 „	0·827 „

188. Variation of Quantity at different periods of life.—The proportion of the different constituents excreted varies, however, as already stated, at different periods of life. The amount of urine excreted, is much greater in proportion to the body weight in children, than in adults. In the fœtus and infant, however, the urine contains a very small quantity of solid matter. In a specimen of fœtal urine, examined by Dr. Moore (Heller's pathology of the urine), no urea was present. I found urea in a specimen taken at the seventh month. It contained also numerous casts of the uriniferous tubes with free epithelium but no albumen. The proportion of solid matter is not more than five parts in 1,000.

In young children of from 4 to 8 years, the mean age being 4 years and 2 months, and the mean weight 31 lbs., the quantity and composition as calculated from analyses by Scherer, Bischoff and others, by Dr. Parkes, is as follows:—

	In 24 Hours.	Per lb. of the body weight in 24 Hours.
Water	10062·0 grains = f ℥ xxiij.	3282·00 grains.
Solid Matter	426·0 „	13·70 „
Urea	178·8 „	5·77 „
Extractives	60·7 „	1·96 „
Fixed Salts	186·9 „	6·03 „

In old age, on the other hand, the solids of the urine are considerably lessened. According to Lecanu, only 125 grains of urea were excreted in twenty-four hours by old people. The uric acid was about the ordinary proportion.

Although, in all works on the urine, tables of the average composition of urine are given, it must not be supposed that the numbers given are true for every individual case. It has been clearly shown, not only that the proportion varies according to the weight of the person, the quantity of food taken, the amount of active excercise, and many other circumstances, but that the proportion of solid matter excreted for every pound weight of the body varies considerably in different individuals, in the same person at different times, and enormously at different periods of life. This, however, is no more than would be expected, since the proportion of the most important of the solid urinary constituents depends directly upon the quantity of matter disintegrated in the organism; and this, as is well known, is much greater in the child than in the adult; while in old age these changes are reduced to a minimum.

189. Average Composition of Healthy Urine, &c.—With a view of giving a rough idea of the general amount of the different urinary constituents excreted, and the proportion which these bear to each other, in twenty-four hours, I have arranged the results of numerous observations in a tabular form. The proportion of some of these substances is so variable, that it is impossible to give an average. In most cases, I have purposely given a round number, and avoided fractional parts; but in other instances, in which I have not been able to institute examinations for myself, and when the question has only been examined by one or two observers, I have given the exact figures published by the authority who has made the matter an object of special study. In constructing this table, I have not attempted to follow any single observer, but, with the exceptions alluded to, have put down numbers which appear to me to be tolerably correct. They have been obtained by consulting numerous authorities, and from my own analyses. This table, therefore, is only to be looked upon as a rough approximation to the truth. In the second column will be found the quantity of each constituent corresponding to every pound weight of the body eliminated in twenty-four hours; in the third column the composition of 1,000 grains of urine is given; in the fourth, the quantity of constituents in 100 grains of solid matter; and in the fifth, the percentage composition of the salts.

The figures in the table may be regarded as the proportion

excreted by a strong healthy man in good nutrition, on full diet. Healthy women would excrete from one-third less to half the quantities given in the first column.

Some exception may be taken to the numbers expressing the *relative* amount of the different ingredients. For instance, the proportion of urea to extractive matters undergoes the greatest variation. Sometimes the urea is double the weight of the extractives, while in other cases the numbers would be almost reversed. Many of the saline constituents also exhibit the greatest variations, not only in different individuals, but in the same person, on different days. Thus the quantity of chlorides is twice as great on some days as on others; depending, as before remarked, partly on the amount taken in the food, partly upon the quantity of fluid and other saline matters. As yet, these extraordinary fluctuations have not fully been accounted for; but, doubtless, in time, the circumstances which determine them will be accurately made out.

Table showing the amount of Urinary Constituents excreted in twenty-four hours, and in 1,000 parts of Healthy Urine, with the percentage composition of the Solid Matter and Fixed Salts.

	Excreted in 24 hours.	Excreted for every pound weight of the body, of an adult weighing 145 lbs., in 24 hours. ‡	In one thousand parts of urine.	In one hundred grains of solid matter.	In one hundred grains of salts.
Specific Gravity 1,015 to 1,025					
Quantity	40 oz. to 60 oz. 17,500 grs. to 26,250 grs.				
Water	16,700—25,050	About 158·63	968·0 —940·0		
Solid matter	800— 1,200	" 8·00	32·0 — 60·0	100·0	
Organic matter	600·0—900·0	" 6·0	24·0 — 45·0	75·0	
Saline matter	200·0—300·0	" 2·0	8·0 — 15·0	25·0	100·00
Urea	400·0 —600·0	" 3·53	12·0 — 30·0	45·0	
Kreatine	3·45*— 6·32*	" ·03			
Kreatinine	5·50*—10·00*	" ·05	·3 — 1·0	1·5	
Uric Acid	5·00 — 8·00	" ·06			
Hippuric Acid	7·50*—30·00†				
Extractives and colouring matter	140·0 —200·0	" 1·06	9·0 — 20·0	20·0	
Free Acid	20·0 — 30·0		·32— ·64	1·0	
Ammoniacal Salts	6·0 — 15·0		1·50— 3·00	5·0	
Mucus	10·0 — 30·0		·1 — ·4	1·0	
Sulphates	50·0 — 85·0		1·5 — 6·0	8·0	30·0
Alkaline Phosphates	60·0 —100·0 or 16		2·0 — 9·0	9·0	38·0
Earthy Phosphates	6·0 — 20·0		·5 — 1·2	1·5	6·0
Chlorides	100·0 —300·0		4·0 — 8·0 or more	7·0 or more	25·0 or more
Chlorine	60·0 —180·0	·88	2·4 — 4·8	about 4·2	15·1
Sulphuric Acid	25·0 — 42·0	·21	·75— 3·0	about 4·0	15·0
Phosphoric Acid	30·0 — 50·0 or 80	·34	1·0 — 4·5	about 4·5	19·0

The numbers in the first column are *high*, and must not be considered to represent the smallest proportions excreted consistent with health.
* Thudichum. † Hallwachs. ‡ The numbers in this column are taken from Dr. Parkes.

190. Observations on Estimating the Excrementitious Substances.—The above table may, perhaps, assist the practitioner in some measure, in remembering the general composition of healthy urine, and the proportion of the different constituents eliminated from the body in twenty-four hours. It is, however, quite impossible to use this or any other table as a standard of reference, because the proportion of the urinary constituents secreted in health is very different in different individuals. Before we can judge if a man is passing too much or too little of any substance, we must ascertain his weight, and form some general idea of the activity of his vital actions when he is in a state of health. For example, the statement that a patient is passing daily 150 grains of urea, indicates nothing; for a small woman in good health, weighing 80 lbs. or less, secretes daily even less than this; but if this amount only were excreted by a tall, strong, active, healthy man, weighing 170 lbs. or more, it would indicate a very serious condition, and we should know from this fact alone that he was in the greatest danger. The secreting structure of his kidneys must be temporarily or permanently affected, and, unless relief could be afforded very soon, death would probably result from the accumulation of excrementitious substances in the blood. If it is proposed to conduct a series of researches with the object of ascertaining the proportion of excrementitious substances produced in, and removed from, the organism, the weight of the individual should always be taken, and the amount of ingesta must be estimated daily. The quantity of excrementitious substances generally, including the sweat, if possible, must be estimated. There is very much to be made out by carefully conducting series of researches of this kind in the cases of patients suffering from various acute affections; and, since the introduction of the volumetric process of analysis, we have had great facilities for conducting such inquiries.

191. Weighing Machines.—In many cases, the most valuable information bearing upon the progress of the case may be gained by the simple process of weighing the patient, which is too seldom adopted. All our hospitals and public institutions ought to be furnished with weighing machines. How often in the course of many diseases one desires to know simply if the patient has gained or lost in weight? The best weighing machines are, unfortunately,

very expensive. A good simple apparatus, which can be made for a moderate sum, is much required. Messrs. Weiss construct an improved apparatus suitable for the practitioner, but the price of this is ten guineas. Mr. Young of Cranbourne Street, W.C., also makes excellent weighing machines. A very useful machine is supplied by Messrs. Pooley, of Liverpool, and Fleet Street, London, which is well adapted for ordinary observation, and costs less than four pounds.

CHAPTER IX.

URINE IN DISEASE.—DIATHESIS.—EXCESS OR DEFICIENCY OF WATER AND THE ORGANIC CONSTITUENTS PRESENT IN HEALTH. *Excess of Water—Diabetes Insipidus—Deficiency of Water —Clinical Remarks on the increased Acidity of Urine—Nitric Acid in the Urine—Alkaline Urine—Uræmia—Ammonia—On Detecting Urea in the Blood or Serum—On Detecting Ammonia in the Breath—Urea—Excess of Urea—Clinical Observations—Deficiency of Urea—Colouring Matter—Tests for Uroxanthine—Colouring Matter of the Blood—Black Pigment—Excess of Uric Acid and Urates—Treatment—Hippuric Acid—Extractive Matters —General Remarks on the Increase of the Organic Constituents—Analyses of Urine in Skin Disease—Analyses of Urine in Chorea.*

URINE IN DISEASE.

192. Morbid Urine.—Before I describe in detail the particular characters in which a specimen of urine may differ from the secretion in its normal state, it is desirable to consider one or two questions of general interest, which can be more advantageously discussed here than in a future chapter.

Many alterations in urine, which have been termed "*morbid*," really depend upon increased or diminished activity of the same chemical changes which occur in health. It is often very difficult to decide how far an alteration in the quantity or quality of the constituents should be attributed to physiological changes, or referred to morbid actions; and it is quite impossible to separate by a distinct line, healthy from morbid actions. An excess or deficiency of the ordinary normal changes may lead to disease. There are many

alterations in the urine, depending upon a temporary derangement of those actions which occur in a state of health, which would not be properly described under the term healthy, but which, nevertheless, cannot properly be called morbid. I do not attempt, therefore, to divide *accurately* healthy urine from morbid urine, and only wish the arrangement adopted in this work to be regarded as a sort of rough artificial division, adopted for convenience alone. Indeed, all such divisions are quite artificial; and no one attempts to assign accurate limits even to large and important branches of natural science, as anatomy, physiology, histology, botany, medicine, surgery, &c., which, merely for convenience, are treated of as separate subjects.

Important changes often occur after the urine has been passed, and may be due to the action of the air, fermentation caused by the presence of mucus, and a number of other circumstances.

The functions of digestion, respiration, and circulation, are intimately concerned in the formation of those substances which are removed from the system in the urine. The characters of the secretion are much affected by the state of the skin and the action of the liver; and there are many other circumstances which may cause an alteration in the urine, independently of those numerous affections to which the urinary organs are exposed. Disease of the secreting structure of the kidney, or of any part of the complicated and extensive efferent channel by which the urine is carried off from the gland, may cause very important alterations in the characters of the secretion. It is of great importance to us, as practitioners, to know that an examination of the urine may materially assist us in endeavouring to ascertain the exact nature and precise seat of the derangement in cases of renal disease, and of the mucous surface and organs connected with the urinary apparatus. Sometimes we are able to diagnose the morbid alteration from an examination of the urine alone; but in almost all cases such an examination will afford important information bearing on the nature of the case. Certain substances, which are ordinarily eliminated in the urine, may, in consequence of morbid actions having been set up, be attracted to other parts of the body, or be eliminated through other channels.

When the kidney itself is affected, the morbid condition may be temporary or permanent; and this can often be ascertained with certainty by examining the urine. The mucous membrane of the

pelvis of the kidney, of the ureter, or of the bladder, may be the seat of the lesion; or lastly, a certain effect may be produced by the growth of adjacent tumours, by causing pressure, altering the structure of the organs, &c.

The *ordinary constituents* may be in greater or less proportion than in health, or certain *soluble substances* not met with in the healthy secretion may find their way into the urine. As I have before remarked, a little mucus from the urinary passages is the only *deposit* which occurs in health. In disease, *insoluble deposits* are commonly met with. Substances which are comparatively, though perhaps not absolutely, insoluble (being soluble in a very large quantity of the secretion), may float upon the surface of the urine, or may be suspended throughout the fluid.

By *microscopical examination*, combined with chemical tests, the nature of a deposit is made out. By *chemical analysis* alone, an abnormal proportion of substances present in health, and the presence of such as are not found in the healthy secretion, can be detected, and the amount estimated.

The various alterations of the urine in disease will be discussed in the following order.

First, excess or deficiency of any of the normal constituents of urine. Secondly, I shall refer to the characters of certain soluble substances in the urine in disease, which are never met with in a state of health. The subject of *urinary deposits* will be subsequently considered.

DIATHESIS.

193. Diathesis.—The word *diathesis* is very frequently used in connection with certain abnormal states of the urine. Before considering the characters of the urine in disease, it is therefore desirable to discuss what is understood by this word. The "uric acid," the "phosphatic," the "oxalic," the "sulphuric" *diatheses*, and others, are constantly spoken of. It is well to consider whether any real advantage is gained by employing this term in the manner in which it is generally used. Although the word has been employed by very high authorities since the time of Dr. Prout, there is great objection to its use as an explanation of the causes of the production of urinary deposits.

In the first place, with reference to the *uric acid diathesis;* this

term has been applied to all cases in which the urine habitually contains deposits of uric acid and urates. The precipitation of uric acid in an insoluble form is due to a change taking place in the urine, at least in the majority of instances, *after* it has been secreted. Excess of uric acid may exist in the urine in two states, *dissolved in the fluid*, and in the form of an *insoluble deposit*. In the first case, the practitioner would not be cognizant of the excess; and a person may be passing a very considerable quantity of urates, in a state of solution, for a long time, without any notice being taken of the fact. On the other hand, a patient's urine may contain only the healthy proportion of uric acid; but this, owing to a change taking place *after* it has left the bladder, might be deposited in an insoluble form. From this circumstance alone, it would be inferred that the last patient had a disposition to the formation of a large quantity of uric acid (*uric acid diathesis*), while really there might be a much larger amount produced and excreted in the former instance.

Secondly; persons whose urine has deposited triple phosphate and phosphate of lime have been said to suffer from the phosphatic *diathesis;* while the deposition of the sediment depends, at least in the great majority of cases, upon a change occurring in the urine after it has left the secreting part of the organ, and has not necessarily anything to do with the habit of body or peculiarity of constitution, or with the state of the blood. But the deposition may be associated with actual and positive excess. Dr. Bence Jones defines the phosphatic diathesis and the sulphuric diathesis in the following terms: —"What I wish to impress upon you now is, that the true phosphatic diathesis—that is, the occurrence of an excess of alkaline and earthy phosphates in the urine—may not make itself apparent to the eye. The alkaline phosphates may be present in an inordinate excess; and, as in the sulphuric diathesis, the sulphates may be immensely increased," &c. (Lectures on Digestion, Respiration, and Secretion, "*Medical Times and Gazette*," March 27th, 1852.)

Now, in these cases, what is observed is, that a greater proportion of certain constituents is excreted in the urine than occurs in perfect health. The different physiological conditions under which an excess of some of these substances is produced are well understood, and the result cannot be referred to any peculiar *habit* or *diathesis*. If we speak of the *sulphuric acid diathesis*, we must, of

course, admit the *urea diathesis;* for usually, when the sulphates are in excess, a corresponding increase in the proportion of urea exists. On the same principle, we might speak of the *extractive diathesis* and the *water diathesis.* It would be quite as fair to talk of the *carbonic acid diathesis* when an increased proportion of carbonic acid was exhaled, &c.

Thirdly; many of the above remarks will apply to the so-called *oxalic diathesis.* The presence of oxalate of lime, and the increase of certain of the materials which exist in health, depend upon the action of well-known chemical changes, and result as the natural consequence of confinement, exposure to cold, particular kind of food, &c. No peculiar diathesis can be discovered in persons who pass urine having these characters: in fact, in the majority of cases, the alteration is only of temporary duration; and it therefore seems to me, that the term *diathesis* is quite inapplicable.

We may in the present state of knowledge, with propriety, perhaps, speak of the *gouty diathesis,** of the *tubercular* and *cancerous diathesis*, and, perhaps, of the *rheumatic diathesis*, because there certainly is a peculiarity of constitution, which may be transmitted from parent to offspring, and which is characterised by the invariable presence of certain morbid actions which exist in the conditions familiar to us, under the terms *gout*, *tubercle*, *cancer*, and *rheumatism.* But of the actual state of the blood, and condition of the vital processes, which lead to the symptoms with which we are so familiar, we really know very little; so that it seems to me better, even in these cases, to say that a patient suffers from attacks of gout, of tubercle, cancer, or rheumatism, than to hide our ignorance of the essential nature of these morbid states under a learned term, the meaning of which cannot be well defined. I shall venture then to discard altogether the use of the word *diathesis* in the discussion of morbid states of the urine.

Excess or Deficiency of Water and of the Organic Constituents of Urine.

194. Water.—The varying quantities of water removed from the body, in different physiological states of the system, have been

* Dr. Garrod has shown that, in gout, the kidney fails to excrete the uric acid in the usual quantity.

already referred to. Every one is familiar with the relations existing between the functions of the skin and intestinal canal, and the kidneys. The same laws hold in disease. If the kidneys be diseased, and the intestinal canal, the skin, and the respiratory apparatus, be tolerably healthy, they, to some extent, fulfil the work of the kidneys. In skin diseases, and in certain affections of the intestinal canal, increased work is thrown upon the renal apparatus. In the treatment of these cases, the practitioner must bear in mind the existence of such relations.

There are certain affections in which the quantity of water removed from the body is greatly increased. In various hysterical and other emotional states, large quantities of pale urine, containing but a small quantity of solid matter, are frequently voided. Some persons habitually pass very dilute urine, which is not very easily explained, but is probably to be looked upon as an individual peculiarity, corresponding to the constant sweating, and to the unusual amount of action of the alimentary canal, occasionally met with in individuals who enjoy good health.

It has been already remarked, that within certain limits water increases the disintegration of tissue; and when a large amount of fluid is taken, the total quantity of solids removed in the urine is greater than in health. When the solids as well as the water are greatly increased in quantity, we should be led to fear the existence of diabetes (Chapter XII.). An unusual quantity of urine of very high specific gravity, and therefore containing a large amount of solid matter, is almost characteristic of this condition.

195. Diabetes Insipidus.—The majority of the so-called instances of diabetes insipidus are cases in which there is great thirst, and a large amount of water is removed from the kidneys daily (*diuresis*); but the total quantity of solid matter is not above the normal standard. In a few of the cases recorded, it would appear that the latter is also much increased; but these must be very rare. There is no sugar in these cases. I have seen instances in which the quantity of water passed as urine was two or three times as great as that said to have been taken in the food; but I firmly believe that deception was practised, and that the patient got water by stealth. In some cases, however, in which very large quantities of urine are voided, there is undoubted evidence of

chronic renal disease. In Vol. II. of my "*Archives*," Dr. Eade alludes to several cases of this disease, and gives notes of two which occurred in men of the ages of 65 and 40. Two of the cases were children. The urine passed by the men amounted to from five to seven pints. Its specific gravity varied from 1,003 to 1,014. The man aged 65 suffered from severe irritation of the bladder, and died in eighteen months. The *post mortem* revealed a bloodless state of the viscera generally. The coats of the bladder were much thickened; the infundibula and pelves of the kidneys much dilated; the left kidney was of the natural size; the right, one-half larger, the cones very hard, pale, and flaccid. In the other fatal case, both kidneys were much wasted. The cones "converted into dense fibrous tissue, containing many large cystiform spaces"; the pelves much enlarged, and the ureters a little dilated. Both supra-renal bodies were "converted into flaccid cysts, capable of containing each some half-ounce of fluid, with their walls having a bile-coloured granular appearance." Dr. Eade sent me the kidneys for examination. I found that many of the tubes in the cortical portion were narrow and much wasted; others were twice the diameter of the tubes in health. The walls of the tubes were thick and firm; the Malpighian bodies were smaller than in health; the epithelial cells smaller and more numerous. The state of the supra-renal bodies in this case has led Dr. Eade to offer the suggestion, that the condition might have originated in some irritative disorder of the supra-renal bodies. ("*Archives of Medicine*," Vol. III., p. 127.)

The following analysis represents the composition of the urine in one of these cases of Hydruria, or diabetes insipidus. It was obtained from a man aged 45, in King's College Hospital, under Dr. Todd. This patient was passing about eleven pints of urine *per diem*, while he was drinking about thirteen pints of liquid. Reaction feebly acid; specific gravity 1002·8.

Analysis 1.

			In 24 hours.
Water	995·91		
Solid Matter	4·09	100·00	394
Organic Matter	2·79	68·22	268
Fixed Salts	1·30	31·78	125

The quantity of urea excreted in twenty-four hours in this case was very small, which confirms the observation of Bischoff, that the

ingestion of a large quantity of water diminishes the excretion of urea. At first, the total quantity passed in twenty-four hours is above the average, because much is washed out from the tissues by the large quantity of fluid; but afterwards it falls, because less is formed in the organism than under ordinary circumstances. The proportion of inorganic salts to the organic constituents of the urine is very high, though the total quantity is less than is passed in health.

In one of Dr. Eade's cases, an analysis of the urine was made by Mr. Sutton. It contained only 9·3 grs. of solid matter in 1,000 grs.; of this, 5·57 grs. consisted of urea. The composition of 100 grs. of the *solid residue* was as follows:—

Analysis.

Urea	60·00
Potash	5·63
Lime	·49
Soda and Magnesia	11·14
Silica	·43
Ammoniacal Salts, &c.	8·62
Sulphuric Acid	3·07
Phosphoric Acid	2·97
Chlorine	7·66

Dr. Strange, of Worcester, has published a very interesting case of diabetes insipidus. ("*Archives of Medicine*," Vol. III., p. 276.) The patient was a boy aged 18, with excessive thirst. He was of small build, but moderately stout. The urine amounted to twelve pints in twenty-four hours, and this large quantity had been passed for years. The specific gravity was 1,007. There was no albumen or sugar. The complexion was ruddy, and there was no pallor or puffiness indicative of renal disease. On admission into the infirmary he was only allowed a limited quantity of fluid to drink, and he was treated with phosphoric acid and nux vomica. Catechu and laudanum were afterwards given to restrain the diarrhœa from which he was suffering. About ten days after admission he became drowsy. A fortnight after admission he was seized with convulsions, and soon became comatose, with dilated pupils and stertorous breathing. The insensibility passed off after he was bled, but again recurred two days afterwards, and soon became profound. He died

with symptoms of cerebral effusion. Both kidneys were reduced to "mere sacs, of from twice to thrice the extent of the healthy kidney! There was complete absence of all proper parenchymatous structure, both tubular and cortical, the sacs being divided into a number of cells by the septa which occur in the fœtal state." The *circumference of the ureters varied from three to four-and-a-half inches.* No urea was found in the fluid in the ureters and sacs. Dr. Strange considers that the condition of the kidneys was mainly due to congenital malformation. He thinks it probable that the sacs were only capable of separating the urea from the blood when in a very dilute form, and considers that the diarrhœa and the diminished quantity of fluid ingested may perhaps have somewhat hastened the fatal result. In all cases of this condition, there is an abundant flow of urine, depending upon the sufferers being excited to drink largely to allay the excessive thirst which they experience. There are languor, debility, loss of appetite, often nausea and vomiting, with weak heart's action, and general loss of power, and sometimes an irritable state of bowels, with diarrhœa. It is certain that many very important points connected with this very interesting disease are yet to be discovered. Every case should be very carefully observed.

196. Treatment.—Two of Dr. Eade's cases improved under tonics and iron. The quantity of fluid allowed should be reduced very cautiously. Dilute mineral acids, especially phosphoric acid, sometimes allay the thirst. The state of the patient's health generally must be considered; and if chronic renal disease exists, the treatment must be conducted according to the general plan followed in this condition. Of all mere remedies, the greatest benefit results from the tincture of sesquichloride of iron, steadily persevered in for months. But the practitioner will, of course, study the whole state of the patient, and not attempt merely to diminish the excessive diuresis.

197. Deficiency of Water is, in the great majority of cases, associated with an abnormal quantity of solid matter. The ingredient which is usually in excess, and to which the urine owes its great density, is urea; so that urine of this character will be more conveniently considered presently. There are cases in which a very small quantity of urine, containing but a small percentage of solid

matter, is passed; but in these *albumen* is generally present, and they will be considered in Chapter XI. When the total amount of urine is very small, and the secretion contains but little solid matter, the secreting structure of the kidney is generally much impaired.

198. Clinical Remarks on the Increased Acidity of Urine.—The causes of the reaction of healthy urine have been already considered in § 119, and it is therefore unnecessary to pursue this part of the subject further. Vogel states that, in chronic and acute diseases, the quantity of free acid is diminished for the most part. In many cases of pneumonia and rheumatic fever, however, the quantity of free acid is much greater than in health.

A highly acid condition of the urine, persisting for a long period of time, may cause the precipitation of uric acid, and so lead to the formation of a calculus. Acid urine not unfrequently causes irritable bladder, and excites other morbid actions. In most cases, the salts of the vegetable acids (citrates, acetates, tartrates), will be found more efficient in counteracting this acid state of the urine, than alkalies or their carbonates, and are less likely to interfere with the digestive process. There are, however, low conditions of the system in which the acid state of the urine, and a tendency to the deposition of uric acid in large quantity, are not relieved by this treatment; on the contrary, such cases are often much benefited by an opposite plan of treatment—tonics and the mineral acids before meals, a nourishing diet, with a moderate supply of simple stimulants with a little alkali, or with alkaline waters. Pepsine is often of great use in these cases. Many of them seem to be intimately connected with impaired digestive power. The acid state of the urine may depend upon very different conditions of the system, and these must be carefully considered in each individual case before any plan of treatment is suggested.

199. Nitric Acid in the Urine.—Dr. Bence Jones ("*Philosophical Transactions*," 1851, p. 399) has been led to the conclusion that ammonia, in its passage through the organism, gives rise to the production of a certain quantity of nitric acid, which is eliminated in the urine. He found that the acidity of the urine was not diminished by giving large quantities of carbonate of ammonia; and that, in some instances, the acid reaction seemed to be increased.

While tartrate of potash soon rendered the urine alkaline, this effect was not produced by the corresponding salt of ammonia.

The following test, suggested by Dr. Price, was employed for the detection of the nitric acid, in preference to the indigo test. By this plan, one grain of nitrate of potash dissolved in ten ounces of urine was detected with the greatest certainty. From four to eight ounces of urine were mixed with half an ounce of strong and pure sulphuric acid, free from nitrous acid. Two-thirds of the mixture were distilled over; and, after being neutralized with pure carbonate of potash, the distillate was evaporated to a very small bulk. From a drop, to half of the residue, was mixed with the following test-solution. To a solution of starch, a drop or two of a solution of iodide of potassium, specific gravity 1,052, and very dilute hydrochloric acid, specific gravity 1,005 were added. If nitric or nitrous acid is present, the iodine is set free, and a blue iodide of starch is at once formed.

Another portion of the residue was placed in a basin, and a very small quantity of indigo, with excess of sulphuric acid, added. If nitric acid was present, upon applying heat for a few minutes, the colour of course disappeared.

From numerous experiments, varied in many ways, Dr. Bence Jones came to the conclusion that ammonia in the organism is partly converted into nitric acid. The nitrogen of the air also, in ordinary combustion, unites with oxygen to form nitric acid. Urea and caffeine, and other substances containing nitrogen, give rise to the formation of a small quantity of nitric acid. Although Lehmann has failed to confirm these results, he has not, I think, succeeded in shaking the evidence in favour of the conclusions.* Dr. Bence Jones brings forward several cases of healthy persons whose urine did not yield a trace of nitric acid; but, three or four hours after they had taken carbonate of ammonia, evidence of the presence of the acid was afforded by the starch and also by the indigo test. After twelve hours, only a trace could be detected; and, in twenty-four, even this ceased to be perceptible. The urine was examined in precisely the same manner in every case. A small amount of ammonia in the

* Professor Lehmann attributed the action upon the iodide of potassium to the presence of *sulphurous acid*. Jaffé performed some experiments in Lehmann's laboratory, and obtained sulphurous acid but no nitrous acid from healthy urine and from urine passed after taking ammoniacal salts. Dr. Bence Jones has subsequently repeated his experiments, and finds that Jaffé's experiments do not invalidate Price's test for nitrous acid as Lehmann supposed. ("*Proceedings of the Royal Society*," Vol. VII., p. 94.)

organism is converted into nitric acid; and it is not improbable that, under certain circumstances, the quantity of nitric acid formed in this manner may be very much increased.

200. Alkaline Urine.—An *alkaline condition* of the urine may be due to several causes, and requires, therefore, to be treated on different plans. The connexion between an alkaline state of the urine, depending upon fixed alkali, and the secretion of a highly acid gastric juice, has been already referred to. In such cases, attention must be paid to the state of the digestive process; and when this is set right, the urine will regain its normal characters. Dr. Bence Jones ("*Medico-Chirurgical Transactions*," Vol. XXXV.) alludes to three cases of dyspepsia with vomiting of a very acid fluid (two of them rejecting sarcinæ), in which the urine became alkaline from the presence of fixed alkali when the quantity of acid set free at the stomach was very great; but, when this was small, the reaction of the urine was acid. It must, however, be borne in mind that the very acid nature of the materials rejected in many cases of vomiting, and especially in cases of sarcina ventriculi, arises, not from the secretion of an acid fluid by the glands of the stomach, but from the decomposition or fermentation of the food when acids are developed, among which may be mentioned acetic, lactic, and butyric acids. At the same time, there can be no doubt that, in many cases of dyspepsia, the feebly acid or alkaline condition of the urine arises from the secretion of an abnormal amount of acid by the stomach. "The degree of the acidity of the urine may, to a certain extent, be regarded as a measure of the acidity of the stomach." (Dr. G. O. Rees, "*Lettsomian Lectures*," 1851.)

Dr. Rees has drawn attention to a large class of cases in which he explains the alkaline condition of the urine as follows:—Urine which is highly *acid* at the time of its secretion, irritates the mucous membrane of the bladder, and causes it to secrete a large quantity of *alkaline fluid*. This mucous membrane in health secretes an alkaline fluid, to protect its surface, just as occurs in the case of some other mucous membranes. Under irritation, more alkaline fluid than is just sufficient to neutralise the acid of the urine is poured out; and hence the urine, when examined, is found to have a very alkaline reaction. In such cases, this highly alkaline condition is removed by giving liquor potassæ or some other alkali, or a salt of a vegetable acid which becomes converted into an alkali in the system. The urine

is not secreted so acid, and therefore does not stimulate the mucous membrane to pour out so much alkaline fluid. I know no observations to disprove Dr. G. O. Rees' explanation of the fact, that in some cases, *alkalies cause the urine to become less alkaline, or even restore its acid reaction;* yet one would hardly expect, if this be the true explanation in cases generally, that the natural reaction of urine would be acid. If there was danger of the healthy mucous membrane suffering from the contact of a fluid only a little more acid than that destined to be continually touching it, should we not expect it to have been of such a character as to resist this action like the mucous membrane of the stomach, instead of being excited to secrete a fluid of such a nature as might lead to its own destruction? Again, the mucous membrane of the bladder bears very well the contact of acid fluids which are sometimes injected; and patients sometimes for years pass intensely acid urine, without the secretion of this excess of alkaline fluid from the mucous membrane.

201. **Uræmia** is the term applied to that condition of the system which soon follows the retention of excrementitious urinary substances in the blood. The condition generally results from long-continued organic disease of the kidneys, but it may depend upon acute disease. The nervous phenomena are generally considered to depend upon the accumulation in the blood of urea, but later researches have shown that neither urea, carbonate of ammonia, nor nitrate of potash, injected into the blood of animals, prove speedily fatal, unless the kidneys be previously extirpated (Hammond). If, however, the quantity of urea injected be very large, death does take place. Stannius, on the contrary, states that urea injected into the blood is harmless; and Petroof has injected a large quantity into the blood without causing coma. Dr. Hammond has shown that the urine, as a whole, is more poisonous than a simple solution of urea. He has proved most conclusively that Frerich's notion—that the urea became decomposed into carbonate of ammonia—is erroneous; and Johnson, Richardson, and others, are of the same opinion. Hoppe finds that, in uræmia, the extractives are increased to three times and the creatine to five times the normal amount.

Dr. Richardson has shown that even water in excess in the blood will produce symptoms resembling those present in uræmia ("*Clinical Essays,*" Vol. I., p. 171); but he agrees with most other observers

in considering that the condition uræmia depends upon the retention of urea in the blood, and its action upon the tissues of the body as a poison.

In considering this question, it must be borne in mind not only that the renal disease has gradually advanced, and that the kidneys, have become almost inefficient, but that most important alterations have been slowly taking place in the blood. Many tissues in the organism have been secondarily affected, and are probably much altered in structure. At present, we are but very imperfectly acquainted with the normal changes occurring in the blood, or with the consequences immediately resulting to the tissues, especially the nervous system, in consequence of the retention of certain excrementitious matters; and we know very little of the remote or immediate effects resulting from certain excrementitious substances not being formed at all. The question is a more difficult one than at first appears, and requires more searching chemical and microscopical investigation than it has yet received. The latest writer on this subject concludes a very elaborate essay thus: "Enfin, cette altération chimique du sang est encore mal définie, et la science attend sur ce point de nouvelles recherches." ("*De L'Urĕmie, These*," par Alfred Fournier, 1863.) At the same time, it is quite certain that the accumulation of urea, and probably other urinary constituents, in the blood, will give rise to uræmia as soon as the proportion reaches a certain amount. This must occur if the formation of these substances proceeds, while, from their damaged state, the kidneys can no longer separate them.

202. Ammonia.—Numerous experiments seem to show that in health a small quantity of ammonia escapes in the urine. Neubauer has conclusively proved that certain ammoniacal salts pass through the organism, and may be detected in the urine unchanged. Ammonia, as is well known, is very easily produced by the decomposition of the urea; but it is almost certain that a small quantity passes into the urine from the blood, independently of that derived from this source.

In disease, the quantity of ammonia present in the urine is often so great as to be smelt all over the room in which the patient lies; but in these cases the ammonia arises from the decomposition of the urea after the urine has left the bladder, and in some it is decomposed even while it yet remains in this viscus.

It is doubtful if a large amount of ammonia under any circumstances accumulates in the blood afterwards to be excreted in the urine, as it is probable that, if formed, it would escape more rapidly from the lungs or intestinal canal. The doctrine that the coma occurring as a sequel to many cases of kidney-disease, depended upon the accumulation in the blood of ammonia produced by the decomposition of urea, was originally put forward by Frerichs. In some of these cases of renal coma, ammonia is present in abnormal quantity. In others, neither urea nor ammonia can be discovered in the blood, while sometimes urea can be detected without difficulty.

I have examined the serum in many cases for urea. Half an ounce of blister serum from a man suffering from renal coma yielded ·54 gr. of nitrate of urea. The patient died shortly afterwards, and urea was detected in the blood and in the brain substance. In another instance, it was detected in the serum of a blister from a man who had had one epileptic fit, depending upon renal disease. In the case of a boy, aged 18, who suffered from epileptic fits, I also detected it in blister serum; as well as in eight ounces of serum from a man suffering from acute dropsy of a week's duration; and I might refer to others in which I obtained undoubted evidence of the presence of urea. There are, however, cases of the same character in which I failed to detect urea, or ammonia resulting from its decomposition.

I have several times examined the breath of such patients, without being able to obtain indications of a larger quantity of ammonia than is afforded by healthy persons. I think, therefore, that we must admit that there are many cases of the so called *uræmic poisoning* which have not yet been satisfactorily explained. It may, however, be urged, that in many cases, although ammonia was formed, it might have been rapidly eliminated from the skin or intestinal canal, so as to escape detection. Bernard and Barreswil have performed some experiments which prove that, after extirpation of the kidneys, urea escapes into the intestinal canal in the form of an ammoniacal salt; and they found that it could not be detected in the blood in less than from twenty-four to forty-eight hours after the operation, when the animal had become weak and exhausted.

Dr. Garrod has detected urea in the blood and blister serum of several cases of gout. ("*Med. Chur. Trans.*" 1848). His results have been confirmed by Dr. W. Budd, who has detected urea in the

blister serum, in nine cases of acute gout, in which there was no indication of renal disease. ("*Med. Chur. Trans.*" Vol. XXXVIII., p. 242.)

203. On detecting Urea in the Blood or Serum.—The urea may be detected by concentrating the serum, after adding a few drops of acetic acid, and extracting with strong alcohol, or the fluid may be evaporated to dryness, and the dry residue treated with boiling alcohol. The alcoholic solution is evaporated to dryness, treated with a drop of distilled water, and two or three drops of strong nitric acid allowed to fall into the syrupy solution. If urea be present, crystals of the nitrate of urea are formed, and may be readily distinguished by microscopical examination. Crystals of nitrate of urea are represented in Plate XI., Fig. 55.

204. On detecting Ammonia in the Breath.—The method of examination which Dr. Richardson recommends is the following:—An instrument in the form of a straight breast-pump is employed to breathe through; a drop or two of hydrochloric acid is placed in the bulb, and a perfectly clean slip of microscope glass placed across the trumpet extremity of the tube, and secured by an India-rubber band. The alkali, as it passes over the bulb, combines with the acid, but some of the acid and alkaline vapours pass over together and condense on the microscope glass. As this becomes dry, crystals are formed (Plate XII., Fig. 65). In health, traces of ammonia are always found in this manner.

205. Urea.—From what has been already said with reference to the variations in the proportion of urea secreted, under different circumstances, in a state of health, it will be inferred that, in disease, the quantity of this constituent varies greatly. The total amount formed in a given time may be much greater or less than in health; and the proportion which this substance bears to the other organic constituents varies greatly in different cases.

206. Excess of Urea.—The term "excess of urea" is not applied to those cases in which the total quantity excreted in the twenty-four hours is much greater than in health; but a specimen of urine which yields crystals of nitrate of urea when an equal bulk of nitric acid is added to it in the cold, without having been previously con-

centrated, is said to contain "excess of urea." The quantity of urea dissolved in the fluid is so great, that a nitrate of urea is formed, and crystallises just as if the urine had been concentrated by evaporation. This result may be brought about in several ways. In cases in which but a small quantity of fluid is taken in proportion to the urea to be removed—when an unusually large amount of water escapes by the skin and other emunctories—and in cases in which an unusual amount of urea is *formed* in the organism, we shall frequently find excess of urea in a specimen of the urine.

Dr. Golding Bird has drawn attention to the frequency of the occurrence of excess of urea with oxalate of lime. The quantity of oxalate of lime, however, is in all cases so very small that it is hardly possible to believe that the formation of this substance can be very important. It will be shown that the oxalate is one of the commonest urinary deposits; that it may result from decomposition of urates; that there is no reason for believing it to be indicative of any peculiar diathesis or habit of body. Excess of urea affords no explanation of the presence of oxalate of lime, nor this latter of urea. Each condition may exist without the other. *Cæteris paribus*, we should expect to find oxalate of lime most frequently present in specimens of highly concentrated urine.

Excess of urea is frequently found in the urine of persons suffering from acute febrile attacks. It is very common in cases of acute rheumatism, and is often met with in pneumonia and acute febrile conditions generally. In England, we meet with these cases very frequently; but, on the continent, they appear to be so rare that many authorities seem to doubt the truth of what English observers have stated with regard to this point. Lehmann, I think, states that he had not seen a case in which crystals of nitrate of urea were thrown down upon the addition of nitric acid, without previous concentration.

The amount of urea excreted is often very great. Vogel mentions a case of pyæmia in which 1,235 grains of urea were removed in the course of twenty-four hours. Dr. Parkes obtained as much as 885 grains in a case of typhoid fever. These quantities are very great, if the patients did not exceed the average weight of adult men; but, unfortunately, the weight was not recorded.

Urine containing excess of urea is generally perfectly clear, of rather a dark yellow colour, and of a strong urinous smell. Its

specific gravity is about 1,030, and it contains generally 50 or 60 grains, or more, of solid matter per 1,000. At ordinary temperatures, an aqueous solution must contain at least 60 grains of urea per 1,000, to form crystals of the nitrate upon the addition of nitric acid without previous evaporation; 50 grains of urea per 1,000 hardly gave the slightest precipitate after the lapse of a considerable time. It would seem that the salts, extractive matters, &c., in urine, cause the crystallisation of the nitrate when even a smaller quantity of urea is present. It should be mentioned, that the above experiments were performed in the summer, in very hot weather. In one case, in which the urea readily crystallised on the addition of nitric acid, the urine had a specific gravity of 1,028, and contained—

Analysis 2.

Water	940·18
Solid Matter	59·82
Organic Matter	50·57
Fixed Salts	9·25

Urine containing excess of urea is generally acid, but I received a specimen from Dr. Fergus, of Marlborough, which was alkaline, and contained crystals of triple phosphate. It came from a patient, 18 years old, who was feverish with gastric and biliary disturbance. The urine was high coloured, sp gr. 1·033, and became nearly solid upon the addition of an equal bulk of nitric acid, from the formation of crystals of nitrate of urea. (April, 1862.)

207. Clinical Observations.—There are some peculiar and not very common cases in which the urine contains this excess of urea; and at the same time more than the healthy amount is excreted in twenty-four hours. The patient is weak, and grows thin, in spite of taking a considerable quantity of the most nutritious food. He feels languid, and indisposed to take active exercise. In some cases, digestion is impaired; in others, the patient eats well, experiences no pain or uneasiness after food, and perhaps has a good appetite. Sometimes there is lumbar pain. It would seem that much of the nutrient material in the blood, instead of being applied to the nutrition of the tissues, becomes rapidly converted into urea, and is excreted. The waste of the tissues is not properly repaired, and

the patient gets very thin. To refer these symptoms to the existence of a particular diathesis, appears to me no explanation of the nature of the case. The pathology of these remarkable cases has not yet been satisfactorily investigated. Mineral acids, rest, shower-baths, and good air, often do good; but some of these patients are not in the least benefited by remedies, and they continue for years very thin, passing large quantities of highly concentrated urine, while the appetite remains good, and they digest a considerable quantity of nitrogenous foods. In one of these cases, which had resisted the usual plans of treatment, benefit was derived from the use of pepsine,* with diminished quantity of meat, and a larger amount of farinaceous food. The condition often lasts for some years.

208. **Deficiency of Urea.**—In chronic disease of the kidney, the urine is of very low specific gravity, and but a very small proportion of urea is excreted in the twenty-four hours. This arises from the alteration in the gland-structure, and the amount of urea separated may be regarded as a rough indication of the extent of the organ involved. In some cases, the morbid condition affects the whole structure; but in others the greater part of the kidney remains healthy. In the latter case, a fair amount of urea will be excreted; and, although the urine contains albumen, the case may be looked upon as a hopeful one. Sometimes the quantity of urea excreted is very small. A lady suffering from an ovarian tumour only excreted 75 grains of urea in 200 fluidrachms of pale faintly alkaline urine in the course of twenty-four hours. (Thudichum). In a case of cancer of the uterus, under the care of Dr. Farre, only a few drachms of fluid were passed from the bladder during a week; and this contained a small quantity of solid matter, in which no urea was detected.

In certain cases, urea almost entirely disappears from the urine, and is replaced by leucine and tyrosine. Frerichs mentions a case of acute yellow atrophy of the liver, in which only a trace of urea could be detected, while a very large quantity of leucine and tyrosine crystallised from the concentrated urine. ("*Klinik der Leberkrankheiten.*" *Erster band. Seite* 221.) In low forms of typhoid

* The pepsine I always use is that prepared, according to a plan I proposed, by Messrs. Bullock & Reynolds, Hanover Street, W. ("*Archives of Medicine,*" Vol. I., pp. 269, 316.) *See* also the paragraphs on the treatment of Diabetes.

fever, the urine also frequently yields leucine and tyrosine in considerable quantity.

In a case of chronic yellow wasting, which came under my own notice (F. C., Vol. vi., p. 37), the liver was of a yellow colour, and weighed 1½ lb. The patient was a young woman, age 26. Jaundice had existed for six weeks, but urgent symptoms—delirium and coma—had only supervened a few days before death. Leucine was obtained from the urine by evaporation, but only in small quantity.

209. Colouring Matter.—The variation of colour of the urine in disease is a matter of great interest; and, although the causes of the change, and the exact nature of the substances which give rise to the peculiar tints often observed, are not yet understood, still there are many valuable observations connected with this subject, some of which I propose to refer to in this place. The colour of urine depending upon blood corpuscles being suspended in it will be discussed under the head of urinary deposits; and now I shall only refer to colouring matters formed in the body and excreted in *solution* in the urine. It should be observed, that pyrola, sumach, and some other substances, alter the colour of the urine. Dr. Hughes mentions cases of dark pigment occurring in the urine of patients taking iodine. These cases, however, are of course not dependent upon morbid changes in the organism.

The principal substance to which the colour of urine is due is probably derived from the blood corpuscles, which are continually undergoing disintegration. This colouring matter becomes altered under different conditions. Much of it is converted into a colouring matter which is separated in the urine, and termed uræmatine (uraphæin, hæmaphine), which is soluble in ether, and, according to the researches of Dr. Harley, is a resinous body, agreeing in some of its characters with the biliary resins.

It is impossible to estimate directly the quantity of the colouring matter present; but Professor Vogel calculates the proportion by ascertaining how much water may be added to the urine to produce a particular tint, which is arbitrarily fixed as the unit of comparison. The quantity of this substance affords an indication of the activity of the disintegration of the blood-corpuscles. In typhoid fever, and many other conditions, this disintegration takes place to such an extent as to produce an anæmic condition. In many acute diseases,

a very large amount of colouring matter occurs in the urine. Urea is not unfrequently present in excess in pneumonia, typhus fever, peritonitis, acute rheumatism, etc. The formation of the urine-pigment is intimately connected with the action of the liver; and, as is well known in diseases of this organ, the urine is frequently very high coloured. Of course, I am speaking of colour independent of the colouring matter of the bile. The deep colour of the urine in diseases of the liver has been often remarked by physicians practising in India; and quite recently my friend Dr. Payne has made some interesting observations on this point, which will be found in the "*Indian Annals of Medical Science*" (Calcutta, Sept. 4th, 1858). In order to detect the colouring matter, Dr. Payne boils the urine, and then adds a drop of nitric acid. Various shades of colour are produced, but at last the mixture becomes of a ruby red. Deficiency of colouring matter occurs in many cases of anæmia. Sometimes the urine is as pale as water.

Heller's observations upon the colouring matter have been alluded to (§ 112). This observer found more uroxanthine (which may be decomposed into indigo blue or uroglaucine, and indigo red or urrhodine) in the urine of persons suffering from diseases of the serous membranes, of the kidneys, and of the spinal marrow, than in the healthy secretion. Schunk, who first separated indigo blue and indigo red, and showed their identity with Heller's uroglaucine and urrhodine, found as much uroxanthine or indican in healthy as in morbid specimens of urine; and he detected it in the urine of thirty-nine persons out of forty. The quantity of this colouring matter is exceedingly small. Schunk, by working on the urine of two persons for several weeks, only obtained one grain of indigo blue.

My friend Dr. Eade, of Norwich, sent me a specimen of urine containing a deposit of uroglaucine obtained from a man eighty-three years of age. ("*Archives of Medicine*," vol. i., p. 311.) Some of these crystals are represented in Plate XII., Fig. 64; and in Fig. 63 are shown some crystals of indigo. *a*, crystals obtained by sublimation; *b*, larger crystals of the same; *c*, small crystals of indigo in fluid. Fig. 64 contains numerous crystals of uroglaucine from the urine. *a*, small collections of a pale blue colour, like Prussian blue; *b*, a darker mass, formed of small spherical masses; *c*, crystals of uroglaucine, of a deep purple or violet colour.

210. Tests for Uroxanthine.—When sulphuric acid is added to urine containing much uroxanthine, a dark blue colour is produced. The mode of employing this test recommended by Dr. Carter, who has made some important investigations on this subject ("*Edinburgh Medical Journal*," Aug. 1859), is as follows:—Urine is poured into an ordinary test-tube, to the depth of half an inch; one-third of its volume of sulphuric acid, specific gravity 1,830, is then allowed to subside to the lower part by letting it fall gradually down the side of the tube; the acid and urine should then be mixed well together. The colour produced varies from a faint pink or lilac to a deep indigo blue colour.

Is uroxanthine to be considered an ingredient of normal urine? As Schunk found this substance in the urine of thirty-nine healthy persons out of forty, and Dr. Carter recently detected it in the urine of three hundred persons (some suffering from disease, others healthy), we may, I think, regard it as a constituent of healthy urine. Dr. Carter has detected it in the blood of several patients—in fact, in every case in which he sought for it. It was also found in the blood of the ox.

Process. The serum was poured off, and a strong solution of diacetate of lead added to it as long as a precipitate was produced. The mixture was then thrown upon a linen filter, and the filtrate was brought to the boiling-point as rapidly as possible in a small flask, in order to coagulate the albumen that had not been precipitated by the lead salt. The solution was then filtered through paper into a vessel placed in cold water; and, when the liquid was cold, a slight excess of caustic ammonia was added. The deposit thus produced, when collected and slightly washed with water, was of a faint yellowish buff colour. The moist precipitate, upon being treated with excess of concentrated sulphuric acid, developed a distinct red colour, owing to the formation of indigo red. The colour was taken up by ether, after the acid had been neutralised by ammonia. The oxide of lead precipitate, from an ounce and a half of blood-serum from a man, forty-three years of age, suffering from acute pleurisy, struck with the acid a distinct lavender colour, which in half an hour passed into a deep red purple. ("*On Indican in the Blood and Urine*," by J. A. Carter, M.D.; "*Edinburgh Medical Journal*," August, 1859.)

Fig. 61.

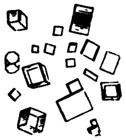

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Fig. 62.

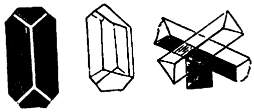

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Fig. 63.

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Fig. 64.

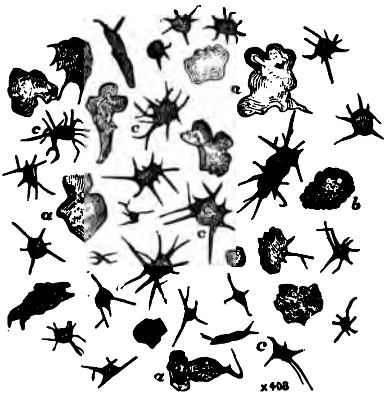

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Fig. 65.

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211. Colouring Matter of the Blood.—The colouring matter of the blood-corpuscles may be present in urine without any corpuscles. In many cases, owing to the rapid disintegration of blood-corpuscles, the serum is highly coloured, and the dissolved colouring matter is excreted by the kidneys. Blood may escape from the vessels into the tubes of the kidney, the corpuscles may gradually become disintegrated, and the colouring matter be dissolved; *hæmatoglobuline* coagulates at a temperature of about 200°, while *albumen* is precipitated at a temperature a little above 140°. In this manner these substances may be distinguished.

There can be little doubt that both the colouring matter of the bile and of the urine are derived from that of the blood-corpuscles. The precise manner in which the change is accomplished has not yet been demonstrated, but it is not improbable that careful observations upon the urine in disease would lead to a solution of this question. That bile-acids and their salts were powerful solvents of blood-corpuscles, was long ago proved by Hühnefield, Plattner, and Simon; and it has lately been shown by Kühne that, by the action of the colourless biliary acids or their salts upon the blood-corpuscles, bile-colouring matter is produced. The bile-acids themselves are not converted into the colouring matter, as Frerichs held; for they pass through the system unchanged. Now, in certain cases where these processes are deranged, it is very probable that the blood-corpuscles are disintegrated in abnormal quantity, and rapidly converted into pigment, which escapes in the urine. The complicated mutual reactions which would ensue when varying proportions of biliary acids, hæmatine, and oxygen, are presented to each other in the living blood, would fully account for the different characters and tints which the colouring matters in urine assume in various cases. Professor Vogel alludes to a case in which the colour of the urine became very dark after the inhalation of arseniuretted hydrogen. Some experiments were made upon a dog, and it was found that the dark colour was due to the disintegration of blood-corpuscles. Albumen was present, but no blood-corpuscles could be detected. A similar disintegration of blood-corpuscles seems to take place in typhoid fever, and in several other diseases.

212. Black Pigment.—Dr. Marcet describes a black pigment which was present in the urine of a child. After the addition of an

acid, some black flocculi were deposited. Professor Dulk gives a case in which a black deposit was separated from the urine by filtration. Other examples are recorded by Dr. Hughes. In three of these cases, creasote had been taken internally; and in two, tar had been applied externally. In one case, a dense black precipitate was thrown down by heat and nitric acid, which was examined by Dr. Odling, who found that, by exposure, it became converted into indigo blue. He draws attention to the close alliance between indigo and the creasote series of compounds, and suggests that, in the above cases, it was derived from the tar or creasote. (Quoted in Dr. Golding Bird's work, fifth edition, edited by Dr. Birkett.)

213. **Uric Acid and Urates** are present in certain proportion in healthy urine, but in disease a large increase is very frequently observed. These substances form urinary deposits, either from existing in too large a proportion to be dissolved in the urine when cold, or, as is probably the case in the majority of instances, from the development of an acid in the urine, which causes them to be precipitated from their solutions. The microscopical characters of these bodies will be considered under the head of urinary deposits. In many acute febrile diseases, the proportion of uric acid is increased, and the period of resolution of the inflammation is marked by diminished frequency of the pulse and respiration, by a fall in the temperature, by free perspiration, and by a very abundant deposit of urates. In health, from 5 to 8 grains of uric acid are excreted in twenty-four hours; but, in some acute diseases, the proportion may amount to twenty grains. In a case of fever, Dr. Parkes found that 17·28 grains of uric acid were excreted in twenty-four hours. Dr. Sansom has estimated the quantity of uric acid in 1,000 grains of the morning urine in health and several cases of disease. The results are as follows:—

	Grains.
Health	·250
Acute Gout	·830
Acute Rheumatism	·802
Heart Disease	.711
Erysipelas	·679
Phosphatic Urine	·140
Chronic Gout	·120
Excessive Debility	·078

Urate of soda is very readily caused to deposit crystals of uric acid. If the amorphous deposit be merely dissolved by warming the urine, the urate often becomes decomposed; and, as the solution cools, crystals of uric acid are deposited. In some cases, the quantity of uric acid held in solution is so great that, upon the addition of a drop of nitric acid to the urine, an abundant amorphous precipitate, exactly resembling albumen, is formed. Such a precipitate has many times been mistaken for albumen (see "*Albuminous Urine*"), and, even if examined under the microscope immediately after it is formed, its nature cannot be made out; but if it be allowed to stand for some time, the amorphous particles gradually increase in size, and assume the well-known crystalline form of uric acid. The instances in which I have met with urine exhibiting these characters have almost all been cases of liver-disease. Although the reaction is acid, no precipitate takes place upon the application of heat, which at once distinguishes urine of this character from albumiuous urine.

The presence of an increased quantity of uric acid in the urine shows that more of this substance or its salts is formed in the blood than in health. It would appear that, in consequence of certain conditions, a large proportion of the uric acid resulting from the disintegration of albuminous substances is not further oxidised and converted into urea, but combines with ammonia, soda, or lime, forming urates of these bases.

In gout, the presence of uric acid in the blood has been shown to be constant by Dr. Garrod, who considers that in this condition "the kidneys lose, to some extent, their power of excreting uric acid," although they eliminate urea as in health. ("*The Nature and Treatment of Gout*," p. 167.) *During* the attack there is less in the urine than in health; but, *after* it is over, a large quantity of uric acid and urates are often carried off from the system in the urine.

214. Treatment of Cases in which the Uric Acid is in Excess.—In cases characterised by a tendency to the formation of much uric acid, the principal objects to be attained by treatment are, to favour the further oxidation of the uric acid formed, and to promote its solution and elimination from the blood as rapidly as possible. Good air and moderate exercise, with attention to the

action of the skin, will fulfil the first object; and the solution and elimination of the urates will be encouraged by giving alkalies in solution in a considerable quantity of water.

The satisfactory change which, in chronic gouty and rheumatic cases frequently ensues from following some of the much vaunted "systems," or going through a course of bathing in Germany or elsewhere, obviously arises from the increased action of the skin, and the improvement of the health generally, effected by the exercise, good air, simple diet, and temperance, wisely enforced in the establishments. If patients could be induced to retire to a pleasant part of the country, where they could take moderate exercise and be free from mental anxiety, meet with agreeable society, live regularly, take small doses of alkalies, and soak themselves for an hour or two a day in warm water in which some carbonate of soda had been dissolved, they would receive as great benefit as by travelling hundreds of miles away, and at much less trouble and expense. I am convinced that there are many patients who would prefer to carry out such a simple plan, rather than submit themselves to all the useless routine and absurd formalities involved in many of the professed universal systems, such as homœopathy, hydropathy, etc., which cannot but be extremely offensive to their common sense,—while they are claimed as converts and supporters of doctrines which they do not really believe in. There are many who, for the sake of the advantage they derive from the regular system of living, air, exercise, etc., express no disbelief in doctrines and propositions which they probably feel to be absurd, and which a little reflection must prove to be false.

In all such cases, the nature of the derangement of the physiological processes should be carefully considered before any plan of treatment is adopted. We must ascertain in what points the condition differs from a healthy state, and then consider how the deranged actions may be restored. It is obviously quite useless to attempt to relieve the patient by giving drugs, without enforcing attention to all the circumstances which are likely to improve the health. Neither will it be wise to attempt to treat the case as if the presence of the uric acid deposit were the most important symptom, for the reasons I referred to when considering the subject of diathesis.

215. Hippuric Acid, as before mentioned, never forms a deposit.* In diabetic urine, it is often found in large quantity, and seems to take the place of uric acid. It is also found in large quantity in the acid urine of fever patients (Lehmann). This fact is of great interest, when considered in connexion with the sugar-forming function of the liver, and the absence of hippuric acid in the organism in certain cases of liver-disease. Kühne has shown that no hippuric acid can be detected in the urine in cases of jaundice; and benzoic acid, which in health is converted into hippuric acid, escapes unchanged into the urine. There can, therefore, be little doubt that this substance is formed in the liver, whether by the action of glycin or glycocholic acid on benzoic acid, or some other substances, has not been determined. When febrile urine is evaporated over the water-bath, crystals of benzoic acid often form on the sides of the basin. This arises from decomposition of the hippuric acid.

To Lehmann's statement, that hippuric acid takes the place of uric acid in diabetic urine, there are many exceptions. I have found a considerable proportion of uric acid in the urine of many diabetic patients, and in several there was an abundant deposit of uric acid crystals.

216. Extractive Matters.—The extractive matters present in healthy urine have been previously described; and I have mentioned that Dr. G. O. Rees has discovered in the urine, in certain cases, an extractive matter which has drained away from the blood, and which is distinguished by producing an abundant precipitate with tincture of galls. Now, although in many cases albumen exists in the same specimens of urine, this blood-extractive sometimes escapes without albumen; and thus the exhaustion and emaciation, in some obscure cases in which there is no hæmorrhage or escape of albumen, are accounted for. The method of testing urine supposed to contain this extractive matter has been described (§ 144). The conclusions at which Dr. Rees has arrived are as follows:—

1. That whenever albumen was present in quantity in the urine, it was always accompanied by the extractives of the blood in large proportion.

2. That the cases in which the extractives of the blood were in the urine in large proportion, were generally those marked by debility.

* Dr. William Budd in certain specimens of urine in cases of gout has observed a flocculent precipitate, which was found to consist of benzoic acid, doubtless resulting from the decomposition of hippuric acid.

3. That cases of anasarca with disease of the heart, and *unconnected with albuminuria*, also showed the extractives of the blood to be excreted by the urine in quantity.

4. That cases of chlorotic anæmia and hysteria give copious precipitates.

5. That when, in albuminuria, the albumen became deficient in the urine, which we know often happens in advanced cases, the blood-extractives also decrease in quantity.

6. That, in cases of anæmia, the proportion of blood-extractives observed in the urine diminished as the cure was proceeding, under the use of ferruginous tonics. (Lettsomian Lectures, "*Medical Gazette*," 1851.)

In many cases where the urine contains an abnormal quantity of water, the proportion of blood-extractives is unusually great. In cases of kidney-disease, the relative proportion of extractive matter to the urea is very much greater than in healthy urine. It would seem that extractives merely filtered from the blood in certain cases, and that these substances might escape into the urine when the structure of the kidney was impaired; but that, for the separation of the urea, a healthy condition of the secreting structure is necessary.

The extractive matters are not capable of being converted, by further oxidation, into urea, carbonic acid, or ammonia; and must, therefore, be regarded as excrementitious substances. Scherer ("*Würzburg Verhandl.*," B iii., Heft II., p. 180.) found that the urea, salts, &c., in the urine of a madman who took no food, were very much diminished; while the extractive matters, although less than in healthy urine, were not diminished in nearly the same proportion as the other urinary constituents.

We know nothing of the circumstances under which the extractive matters may be formed in greater quantity than in health, nor the effects which would result from their accumulation in the blood.

217. General Remarks on the Increase of the Organic Constituents of Urine.—The circumstances under which these constituents are excreted in increased quantity have been already considered, and I propose now to direct attention to a few analyses of the urine in cases of disease in which this character is observed. In almost all forms of fever, in internal inflammations, in acute

rheumatism, in many skin-diseases, and in all conditions in which there is increased action of the muscular system, the solids are considerably above the healthy standard; but the various constituents do not suffer augmentation in an equal degree. In the conditions just referred to, the increase principally affects the organic matters. Sometimes all the ordinary constituents of the urine are excreted in increased proportion, Dr. Lehmann ("*Archiv des Vereins für gem. Arb. zur Förderung der wissench.*" *Heilkunde. Erster Band, Seite* 521), has shown that immersion in the sitzbath, at a temperature of 48° to 60° Fahr., for a quarter of an hour, causes an increase in the quantity of urine, not only of the water, but also of the solid matter. The uric acid, the urea, and the fixed salts, were considerably increased. These results were obtained by estimating the constituents in urine passed during six hours on certain mornings when a bath was taken, and upon others when the observer did not bathe.

The mean of eight analyses of the urine passed during six hours is as follows:—

	Mornings on which the bath was taken.	Mornings on which the bath was not taken.
Water	443·454 grams.	258·456 grams.
Solids	19·403 „	14·459 „
Urea	10·396 „	7·080 „
Uric Acids	0·130 „	0·108 „
Fixed Salts	6·982 „	4·821 „
Volatile Salts and Extractive	1·89 „	2·45 „
Chloride of Sodium	5·814 „	4·319 „

218. Urine in Skin Diseases.—In the following analyses of urine in cases of skin disease, the solid matter is increased; and it will be noticed that the proportion of fixed salts to the organic matters is greater than in health. In No. 4, the quantity of the extractive matter exceeds that of the urea.

Analysis 3.—Urine from a case of eczema, with crusts over the whole body: specific gravity, 1,025.

Analysis 4.—From the same patient on the following day.

Analysis 5.—From a case of eczema, in a boy, aged 18: specific gravity, 1,033; acid, pale colour. Contains much uric acid.

Analysis 6.—From a case of ichthyosis, in a girl, aged 15: acid; specific gravity, 1,032.

219. Urine in Chorea.—In the second series of analyses of the urine in chorea, the principal points to be noticed are the large amount of solid matter, the increase being caused principally by the organic matters. In Analysis 11, the proportion of sulphates is seen to be increased. This increase of sulphuric acid is always observed in cases where the urea is increased.

Analysis 7.—From a girl, aged 10, recovering—after having been ill for several weeks. The urine contained a great number of Cayenne pepper crystals of uric acid.

Analysis 8.—From a girl, aged 12: specific gravity, 1,033; no albumen; much deposit of urates.

Analysis 9.—From a girl, aged 14: specific gravity, 1,035; acid; turbid, from the presence of urates. Uric acid deposited in the urine=·46 per 1,000 parts.

Analysis 10.—From a girl: specific gravity, 1,030; acid; pale in colour.

Analysis 11.—From a boy, about 10 years of age.

Analysis 12.—From a boy, aged 14: acid; specific gravity, 1,034·2.

Analyses.

	3		4		5		6	
Water	948·7		926·1		935·4		929·70	
Solid Matter . . .	51·3	100·00	73·9	100·00	64·6	100·00	70·30	100·00
Organic Matter . . .	27·9	54·6	51·70	69·97	47·91	74·17	48·35	68·77
Saline Matter . . .	23·4	45·40	21·20	30·03	16·69	25·83	21·95	31·20
Urea			24·03	32·51				
Extractives . . .			27·21	36·82			48·35	68·77
Uric Acid . . .			·46	·62				
Alkaline Salts . .	23·4	45·4	21·23	28·72	16·69	25·83	21·95	31·2
Earthy Salts . . .			·97	1·31				
Chloride of Sodium . .					3·99	6·17	1·74	2·47
Sulphates . . .					9·45	14·62		
Phosphoric Acid . .					2·64	4·08		

Analyses.

	7		8		9		10		11		12	
Water . . .	918·75		917·90		930·4		936·8		922·60		915·44	
Solid Matter . .	81·25	100·00	82·10	100·00	69·6	100·00	63·2	100·00	77·40	100·00	84·56	100·00
Organic Matter .	66·53	82·05	68·50	83·45	51·95	74·65	48·75	77·14	50·79	78·55	65·68	77·68
Saline Matter . .	14·62	17·95	13·60	16·55	17·65	25·35	14·45	22·86	16·61	21·45	18·88	22·32
Urea . . .	30·09	37·03	41·10	50·06	25·33	36·39	29·78	47·12	34·29	44·30	64·69	76·50
Extractive Matter.	35·27	43·40	27·4	33·37	26·16	37·58	18·52	29·30	26·21	33·85		
Uric Acid . .	1·27	1·5			·96	1·30	·45	·71	·29	·38	·76	·89
Urate of Soda .											·43	·50
Alkaline Salts .	13·53	16·65	12·83	15·62	17·16	24·94	13·69	21·66	16·07	20·76	18·88	22·32
Earthy Salts .	1·09	1·3	·77	·93	·29	·41	·76	1·20	·54	·69		
Chloride of Sodium									3·35	4·32	2·78	3·29
Sulphuric Acid .									3·54	4·57	5·81*	6·87*
Phosphoric Acid .									1·17	1·51		

* Sulphate of soda.

CHAPTER X.

Urine in Disease—Excess or Deficiency of the Inorganic Constituents present in Health—Urine in Pneumonia—Chloride of Sodium: its Diminution in Acute Inflammation—Urine in Elephantiasis Græcorum—Excess of Sulphates—Increase in Cases of Chorea, Rheumatic Fever, &c.—Influence of Remedies—Excess and Deficiency of Alkaline Phosphates—Increased Secretion of Alkaline Phosphates in Inflammation of the Brain (?)—Dr. Bence Jones' Observations—Analyses—The Author's Observations on the Phosphates—Paralysis of the Insane—Acute Mania with Paroxysms—Chronic Inflammation of the Brain—Epilepsy—Delirium Tremens and Puerperal Mania—Phosphates in Healthy Urine—Variation in the Quantity—Earthy Phosphates—Increase in the Urine of Cases of Mollities Ossium—Analyses—Excess of, as distinguished from mere Deposits of, Earthy Phosphates.

Excess or Deficiency of the Inorganic Constituents.

In disease, the inorganic salts vary greatly in quantity. Sometimes the saline constituents are very deficient. In cases of diabetes, sometimes, there are only traces of fixed salts. This deficiency may depend upon the nature of the food, or it may be due to the *formation* of a diminished proportion of some of the salts in the organism. The sulphates, and the phosphates in part, being formed in the body, will vary under many circumstances.

In some conditions of the system, when much disintegration of tissue or red blood corpuscles takes place, a greater quantity of sulphur and phosphorus is oxidised, and the corresponding acids are formed in unusually large proportion, and excreted in the urine.

In certain inflammatory conditions of the system, it would appear that the chloride of sodium, being required in considerable quantity at the seat of the inflammatory change, is prevented from passing off from the system in the urine. In disease of the kidney, it is important to notice if the proportion of the saline constituents to the organic matter is very much increased. In some states of renal disease, in which the secreting structure of the kidney is so much impaired that the separation of urea and organic matter is interfered with, a proportion of saline matter, considerably larger than that which is present in the urine in health, escapes.

220. Urine in Pneumonia. Chloride of Sodium.—The fluctuations observed in the quantity of common salt excreted in the urine are very great even in health. The circumstances which affect the proportion of chloride of sodium are very numerous, and these are greatly increased in disease. It was found by Redtenbacher, many years since, that in pneumonia the quantity of chloride in the urine gradually decreased as the inflammation advanced; and that in many instances, when the lung became hepatised, not a trace could be detected in the urine. Some years ago, I determined quantitatively the amount of chloride in the urine from day to day, in several cases of acute pneumonia. ("*Med. Chir. Trans.*," Vol. XXXV.) The following case illustrates very well the changes which occur in the urine in this affection.

The patient was a plasterer, aged 24, and was under the care of Dr. Budd, in King's College Hospital. On the third day of the disease, there was dulness two inches below the left mamma in front, and behind over the space below the spine of the scapula. Bronchial breathing and bronchophony were audible over the lower angle of the scapula. Expectoration viscid, frothy, and slightly rusty. Pulse 144, small and weak. Respiration 52.

On the fourth day of the disease, bronchial breathing and bronchophony were more distinct. Pulse 116. Respirations 28. He was treated with small doses of antimonial wine, and was placed upon milk diet and beef-tea. Turpentine stupes were applied to the chest. He progressed favourably; was convalescent within three weeks after the commencement of the attack, and was discharged well in little more than four weeks.

Analysis 13. *Fourth day* of the disease. Urine high coloured; acid; specific gravity, 1,017; contained a little albumen.

Analysis 14. *Fifth day.* Acid; specific gravity, 1,013; natural colour.

Analysis 15. *Sixth day.* Acid; specific gravity, 1,016; pale; still contained a trace of albumen.

Analysis 16. *Tenth day.* Acid; specific gravity, 1,022; no albumen.

Analysis 17. *Twenty-second day.* Acid; specific gravity, 1,016; pale; no albumen.

Analyses.

	13		14	15	
Water	956·60		957·40	954·00	
Solid Matter	43·40	100·00	42·60	46·00	100·00
Organic Matter	40·28	92·82		44·64	97·05
Fixed Salts	3·12	7·18		1·36	2·95
Chloride of Sodium	0		traces	0	

	16		17	
Water	955·00		968·40	
Solid Matter	45·00	100·00	31·60	100·00
Organic Matter	42·12	93·64	23·26	73·61
Fixed Salts	2·88	6·4	8·34	26·39
Chloride of Sodium	0		4·56	14·43

The decrease of the fixed salts generally, during the stage of hepatisation is remarkable. The last analysis of the urine, when the patient was well, shows the healthy proportion. In Vol. XXXV. of the "*Medico Chirurgical Transactions*" will be found several other cases showing similar results. In some of the cases, it was shown that, although there was not a trace of chloride in the urine, and the blood contained less than its normal proportion, the *sputa were very rich in chloride of sodium.* In one case, the proportion amounted to upwards of 18 grains in 100 of the solid matter of the sputum. In a fatal case, much chloride was found in the products effused into the air-cells of the lung. In most exudations, and in growing tissues, there is a considerable amount of chloride of sodium. In acute inflammations generally, the proportion of chloride in the urine gradually diminishes until the disease is at its height. When resolu-

tion occurs, the chloride reappears, and gradually increases as convalescence advances, until it attains its normal standard. The amount of chloride in the urine is much influenced by the nature of the food, and by the quantity of fluid taken, as I remarked when treating of the chloride in healthy urine; but the results above described cannot be explained in this manner; for, although patients take less food when they are ill, and therefore less salt, the same results are observed if salt be given to them. Moreover, the disappearance is gradual, and the reappearance is marked by a change in the symptoms of the disease, although the food has remained the same during the whole period of the illness.

There can be little doubt that, in these cases, the chloride is gradually separated from the blood in undue proportion at the point where the inflammatory changes are taking place; and that, instead of passing through the organism as it does in health, it accumulates at this point until a certain stage of the morbid process is passed, when the cells, which have been growing and multiplying so fast, die and become disintegrated and dissolved, the products thus formed with the chloride of sodium being reabsorbed into the blood, and afterwards altered and at length excreted by the ordinary channels. The precise office which the salt plays in these processes is not understood; but certainly, in all the specimens of inflammatory lymph that I have examined, I have always found common salt present in large quantity. In many cases of bronchitis, acute rheumatism, pleurisy, in some cases of skin-disease, and in some other instances in which its absence would appear to be merely an accidental circumstance, no salt can be detected in the urine. We cannot, therefore, regard this diminished proportion or absence of chloride in the urine as a point of any value in the diagnosis of pneumonia, although it must be looked upon as a fact of great interest with reference to the morbid changes which are taking place at the time. The conclusions to which I arrived, after examining the urine, blood, sputum, and inflammatory products, in several cases of pneumonia, are as follows:—

1. That in pneumonia there is a total absence of chloride of sodium from the urine at or about the period of hepatisation of the lung.

2. That, soon after resolution of the inflammation, the chloride is again present in the urine, and often in considerable quantity.

3. That, at this period (resolution), the serum of the blood is found to contain a greater amount of chloride than in health.

4. That the presence of chloride of sodium in the urine may be taken as evidence of the existence of a greater quantity of the salt in the blood than is required for the wants of the system generally, or, at least, of an amount sufficient for that purpose; and that the absence of the salt from the urine indicates that the circulating fluid contains less than the normal quantity.

5. That the sputa in pneumonia contain a greater quantity of fixed chloride than healthy pulmonary mucus, if there be not much less than a normal amount in the blood, although there be a complete absence of the salt from the urine. In all cases, however, there is found in the sputa a quantity many times greater than exists in an equal amount of blood at the same period of the disease. The absolute amount present is subject to variation at different periods of the disease, and in different cases.

6. That, in one case which was fatal, the proportion of chloride present in the sputum underwent a decrease, while the amount of solid matter, and especially the extractive matters, increased in quantity. At the same time, the sputum became acid; and in the matters expectorated within the last few hours of the patient's life, a large quantity of grape-sugar was found; but, in that obtained on the day previous to his death, none could be detected.

7. The absence of chloride of sodium from the urine during the stage of hepatisation seems to depend upon a determination of this salt to the inflamed lung; and, when resolution occurs, this force of attraction ceases, and whatever salt has been retained in the lung is reabsorbed, and appears in the urine as usual.

221. On the effects of Diuretics and Sudorifics in certain Acute Inflammations.—The increased secretion of urine, the profuse sweating, often accompanied with increased action of the bowels, which mark the occurrence of resolution of the inflammation or the death of the cells entering largely into the formation of the lymph, are undoubtedly encouraged by giving acetates, citrates, carbonates, and some other salts. Indeed, it is almost certain that, in many cases, these critical discharges take place at an earlier period in consequence of the action of the remedies. If profuse sweating and diuresis can be brought about quickly, it is even a question if the

disease may not sometimes be cut short. How can the action of this class of remedies be explained? There can be no doubt that, by an increased action of the excreting organs, many substances which would have been absorbed by the growing cells are eliminated, but it is probable that the salts given in these cases act favourably in another and not less important manner. Chloride of sodium seems absolutely necessary to the growth of the inflammatory products, while the salts given as medicines exert an unfavourable influence, and, the latter being in the blood in considerable quantity, would be poured out at the seat of inflammation, and take the place of the chloride of sodium, driving out the latter. Under these conditions the cells soon cease to multiply, die, and undergo disintegration, the products being absorbed and afterwards excreted.

222. Urine in Elephantiasis Græcorum.—Analysis 18 represents the composition of the urine in an extreme case of *elephantiasis Græcorum*, occurring in a boy about twelve years of age, who was in the hospital some years ago, under Dr. Todd. The emaciation was extreme, and there were a great number of large ulcerated tubercles all over the body, which discharged freely. The absence of the chloride may, perhaps, be accounted for by the presence of exudation and cell development at the bases of these numerous ulcers. The urine was acid; specific gravity 1,020.

Analysis 18.

Water	960·0	
Solid matter	40·0	100·00
Fixed salts	·51	11·27

The ash consisted of sulphates and phosphates, with a mere *trace of chloride.*

Analysis 19.

Another specimen about two months after the last. Specific gravity, 1,014; acid.

Water	965·1	
Solid matter	34·9	100·00
Urea	13·97	40·02
Extractives . . .	16·06	46·01
Uric acid . . .	·31	·88

Alkaline salts . . .	4·07	11·66
Earthy salts . . .	·49	1·40
Sulphuric acid . . .	·422	1·20
Phosphoric acid . . .	1·389	3·98
Chloride of sodium . . .	*not a trace.*	

223. Urine in Hysterical Coma.—It is difficult to account for the absence of the chloride in the following analysis. The urine was obtained from a woman, aged 31, suffering from hysterical coma. About eleven ounces were drawn off by a catheter. The patient was quiet; skin cool; tongue covered with a thick white fur; pulse 135; respiration 18; sensation very much impaired. The patient did not notice a very severe pinch with the nails.

Analysis 20.

Water	921·41	
Solid matter	78·59	100·00
Uric acid	·57	·72
Urea extractives, &c. . .	67·70	86·15
Fixed salts . . .	10·32	13·13

The salts contained sulphates and phosphates, but *not a trace of chloride* was present.

224. Excess of Sulphates: Action of Liquor Potassæ.—I have already observed that the proportion of sulphates usually varies according to the urea; and it follows that, in diseases characterised by a considerable disintegration of muscular tissue, we shall find an unusual amount of sulphate in the urine. In *chorea*, the increase of the sulphates and urea is often very considerable; but there are conditions in which the increase of the sulphates does not appear to be associated with the formation of urea to a correspondingly large amount. An increase in the quantity of sulphate in the urine, in cases of *rheumatic* fever, is noticed in some of Dr. Bence Jones' analyses. In one case, on the fifth day, the urine had a specific gravity of 1,026, and yielded 11·89 grains of sulphate of baryta.

Dr. Parkes has shown, by some very careful experiments on four cases, that in rheumatic fever the sulphuric acid is greatly increased. In one case, 52½ grains of sulphuric acid and 5½ grains of unoxidised sulphur were excreted in twenty-four hours. The urea was not increased in the same degree. This increase of sulphate is not ob-

served in typhoid fever and scarlatina. It *does not*, therefore, depend merely on increase of temperature. Dr. Parkes suggests that in the blood, in acute rheumatism, there may exist a material richer in sulphur than albumen. Potash increases the tendency of this substance to disintegrate; and hence, whenever liquor potassæ is given, the proportion of sulphates in the urine is augmented.

Urinary constituents.	Condition in Rheumatic Fever.	Effect produced by Liquor Potassæ in large doses.
Solids	Increased	Still more increased.
Water	Greatly diminished	Slightly increased.
Uric acid	Increased	Slightly increased.
Sulphur	In considerable quantity	Probably increased.
Chlorine	Diminished	Unaffected.
Sulphuric acid	Greatly increased	Still more increased.*

In many cases of skin disease, I have found the relative proportion of the sulphates to be considerably augmented. This is well illustrated in Analysis 5 (p. 169), which gives the composition of the urine of a boy suffering from eczema.

225.—Excess and Deficiency of Alkaline Phosphates.—Much has already been said upon the quantity and origin of the alkaline phosphate in the urine; and I have brought forward evidence to show that the greater part of the phosphoric acid eliminated, is carried into the organism in the food. A certain proportion, however, there can be little doubt, is formed in the body by the oxidation of the phosphorus of albuminous textures (nervous tissue?). In diseases generally, the alterations which have been observed in the quantity of phosphate removed in the urine is to be attributed, to some extent, to the altered diet of the patient. It is reasonable to suppose that, in some conditions of the system in which a more than usual disintegration of tissues rich in phosphorous takes place, more phosphoric acid is formed in the organism than in health. This excess should be found in the urine in the form of alkaline phosphate, and the amount ought to correspond to the activity of the changes taking place. By ascertaining the proportion, we should be able to form an estimate of the quantity of phosphorus oxidised—and therefore of the nerve-tissue disintegrated—of which it was a component part. The really difficult part of the inquiry is to ascer-

* The influence of liquor potassæ on the urine in rheumatic fever. ("*Med.-Chir. Review*," vol. xiii., p. 248.)

tain how much of the total proportion of phosphate present is derived from the food, and how much is actually formed in the organism. The sulphuric acid is almost entirely produced in the body; and there is not, therefore, the same difficulty in estimating the amount of sulphur oxidised, as there is in the case of the phosphorus.

Of late, the importance of this subject has been much increased by attempts to advance the experimental results already obtained in favour of the hypothesis, that the amount of phosphate excreted in the urine is to be regarded as an index of the activity of the nervous system. Those who labour to prove that all the changes in the body are the direct result of certain chemical decompositions, have not hesitated to bring forward these results in favour of their theory. It seems by some to have been regarded as a settled point, that the quantity of phosphate in the urine varies according to the amount of nervous tissue disintegrated; and it has been assumed that the quantity of work done by the brain is in direct proportion to the activity of the chemical changes going on in the nervous tissue. This question is obviously a most important one, and much more is involved in it than at first appears. I propose, therefore, to examine some of the most important facts which have been ascertained; and I think I shall be able to prove that, in this matter, speculation has, to some extent, taken the place of reasoning founded upon facts and experimental observations.

226. Dr. Bence Jones' Observations on the Alkaline Phosphates.—Dr. Bence Jones, as is well known, has written several important papers upon this subject. The general conclusions to which he has arrived are the following:—

"In delirium tremens, and in other delirium, a remarkable increase in the amount of sulphates in the urine was frequently observed; and the total *phosphates were in the same cases occasionally remarkably diminished.*

"In acute inflammatory diseases of the nervous structures, during the most febrile symptoms, an increase was observed in the amount of sulphates in the urine; and the total amount of *earthy and alkaline phosphates in these diseases appeared to be increased in the same proportion as the sulphates were increased.* ("*Phil. Trans.*," 1850, p. 66.)

"In fractures of the skull, the phosphatic salts increase only

when any inflammatory action occurs in the brain; and in *acute phrenitis, an excessive increase takes place. In delirium tremens, there is a marked deficiency of phosphates,* unless they are introduced with the ingesta; an excess is, however, met with in some functional affections of the brain."

These conclusions are founded upon analyses of 1,000 grains of urine, in eleven cases of delirium tremens and eight cases of acute inflammatory affections of the nervous centres. From these I select a few of the extremes.

Delirium Tremens and other forms of Delirium.

Case.	Sulphate of baryta per 1,000 grains of urine.	Specific gravity.	Total phosphates.
8. Delirium Tremens—thirteenth day	13·10	1037·4	9·83
10. Poisoned by laudanum; delirium and excitement—second day	7·83	1026·8	7·53
4. Delirium Tremens—tenth day .	17·31	1024·74	0·87
11. Delirium with phthisis—fourth night	6·97	1024·2	0·72
Inflammatory diseases of Nervous Structures, with Head Symptoms.			
2. Inflammation of the brain—twelfth day . . .	3·96	1018·7	5·14
Ditto—thirteenth day . . .	11·23	1027·26	11·13
6. Inflammation of lungs, with tubercles and violent head symptoms—fourth day . .	8·55	1027·85	7·19
Ditto—sixth day . . .	7·81	1026·1	6·43

The quantity of urine passed by the patients in twenty-four hours is not stated, nor is the amount of solid matter in 1,000 grains of urine, given. It is, therefore, not possible, from the above data, to form an estimate of the total quantity of phosphate *removed from the organism in twenty-four hours.* Although many of the results, as far as they go, certainly favour the above view, and especially when the numbers are considered with reference to the amount of solid matter estimated from the specific gravity, the increased excretion of the phosphates, in cases of inflammation of nervous structures, is not established by these observations.

227. The Author's Observations on the Phosphates.—I have estimated the quantity of phosphate in urine in various cases of disease. Some time since, I examined the urine of many patients in

St. Luke's Hospital, for Dr. Sutherland, with the view of ascertaining the proportion of phosphates excreted in different cases of mania, dementia, paralysis of the insane, &c. ("*Med. Chur. Trans.*" Vol. XXXVIII., p. 261.) Forty-two analyses were made, and the following formula was filled up in each case.

Water	
Solid matter	
Organic matter	
Saline matter	
Phosphate precipitated by chloride of calcium and ammonia	

Some interesting facts were made out, and the quantity of phosphates relatively to other constituents of the ash differed much from the healthy standard. Some of the results confirmed, as far as they went, Dr. Bence Jones' conclusions; but I do not think we can form a very positive conclusion from these data, seeing that, in some of the cases, the solid matter contained 10 or 12 per cent. of mixed phosphate; while in others only 3 or 4 per cent. was found; and this variation did not always correspond to a difference in the symptoms. I subjoin a few of the most interesting results from two of the series of cases.

228. Paralysis of the Insane.—*Analysis* 21. From a man, aged 36. First attack. It lasted two months. Complete recovery.

Analysis 22.—From a man, aged 45. First attack, of one month's duration. Not relieved.

Analysis 23. From a man, aged 42. The specimen was taken on a day when he was very violent and noisy.

Analysis 24. From the same, about three weeks afterwards, when the excitement had passed off.

Analyses.

	21		22	
Reaction	Acid.		Feebly alkaline.	
Specific gravity . . .	1030		1015	
Water	912·6		959·4	
Solid matter . . .	87·4	100·00	40·6	100·00
Fixed salts . . .	21·42	24·50	13·31	32·7
Phosphate of lime precipitated by chloride of calcium and ammonia .	5·18	5·92	1·57	3·86

	23		24	
Reaction	Neutral.		Acid.	
Specific Gravity . . .	1008		1016	
Water	988·6		958·2	
Solid Matter . . .	11·4	100·00	41·8	100·00
Fixed Salts . . .	4·74	41·57	8·45	20·21
Phosphate of lime precipitated by chloride of calcium and ammonia .	2·90	25·44	2·86	6·84

It is important to observe that, in Analyses 23 and 24, 1,000 grains of urine contained almost exactly the same quantity of phosphates, but that the proportion to the other constituents was very different; the solid matter, in the first case, containing the very large proportion of 25·44 per cent.; in the second, only 6·84 per cent.

229. Acute Mania, with Paroxysms.—*Analysis* 25. From a man, aged 18, with meningitis. The present is the first attack, and has lasted three months. He recovered.

Analysis 26. From a woman, aged 55. First attack, which has lasted about three months. She recovered.

Analysis 27. From a man, aged 26. First attack, which has lasted six days. There was much exhaustion and emaciation. Weighs 7 st. 12 lb. Discharged uncured.

Analysis 28. From a girl, aged 18. Second attack. Weighs only 6 st. 6 lb.

Analyses.

	25		26	
Reaction	Acid.		Feebly Acid.	
Specific Gravity . . .	1020		1023	
Water	945·8		943·00	
Solid Matter . . .	54·2	100·00	57·60	
Fixed Salts . . .	12·91	23·81	15·10	26·49
Phosphate of lime precipitated by chloride of calcium and ammonia .	6·05	11·16	7·14	12·52

	27		28	
Reaction	Acid.		Acid.	
Specific Gravity . . .	1033		1028	
Water	908·00		931·6	
Solid Matter . . .	92·00		68·4	
Fixed Salts . . .	13·18	14·32	20·33	29·72
Phosphate of lime precipitated by chloride of calcium and ammonia.	9·73	10·57	4·49	6·56

It is much to be hoped that such observations will be further carried out by those who have the opportunity. Most valuable results would certainly be obtained, if the urine could be carefully collected for the twenty-four hours.

The conclusions at which Dr. Sutherland arrives, in his paper above referred to, are the following:—

1. A plus quantity of phosphates exists in the urine in the paroxysms of acute mania.

2. A minus quantity exists in the stage of exhaustion in mania, in acute dementia, and in the third stage of paralysis of the insane.

3. The plus and minus quantities of phosphates in the urine correspond with the quantitative analysis of the brain and of the blood; for a plus quantity of phosphorus is found in the brain, and a slight excess of albumen in the blood of maniacal patients; and a minus quantity of phosphorus and albumen are found in the brains of idiots, and a minus quantity of albumen in paralysis of the insane.

4. The plus quantity of phosphates in the urine of cases of acute mania denotes the expenditure of nervous force, and is not a proof of the existence of acute inflammation in this disease.

I have selected the following analyses from my note-book:—

230. Chronic Inflammation of the Brain.—*Analysis* 29 shows the proportion of phosphates in the urine of a man, aged 34, who had been suffering from a tumour pressing on the veins of Galen, causing dropsy of the ventricles of the brain. There were many symptoms of chronic inflammation. Specific gravity, 1,018; acid.

Analysis 30. Three weeks after the first analysis; acid, clear, pale; specific gravity, 1,015.

Analysis 31. After another interval of three weeks; clear, natural colour specific gravity, 1,016.

Analyses.

	29		30	31	
Water	962·10		1000·00	956·3	
Solid matter	37·90	100·00		43·70	100·00
Organic matter	27·09	74·12		33·72	77·17
Fixed salts	9·81	25·88		9·98	22·83
Phosphate of lime precipitated by chloride of calcium and ammonia	2·74	7·22	3·53	3·92	8·97

231. Urine in Epilepsy.—*Analysis* 32. From a man suffering from epileptic fits, occurring every five or ten minutes, for seventeen hours. He breathed stertoriously the whole time, and no urine could be obtained during this period. Urine was obtained on the next day (June 10th); acid; specific gravity, 1,024. Contained an abundant deposit of urates.

Analysis 33. From the same patient, on the 12th; acid, 1,024. Contains a good deal of pus.

Analysis 34. From the same patient, on the 19th; alkaline, 1,017.

Analysis 35. From a very intemperate patient, aged 59, who had epileptic fits every few minutes for thirty hours, followed by exhaustion (twelve hours) and death. There was complete loss of consciousness.

Analysis 36. From a man, aged 53, suffering from slight general paralysis, with impaired speech (slight), intellect, and memory. Duration of illness, three years. Urine, pale, clear; no albumen; feebly acid; specific gravity, 1,009.

Analyses.

	32		33	
Water	931·2		927·2	
Solid matter	68·80	100·00	72·80	100·00
Organic matter	58·35	86·27	51·01	85·18
Fixed salts	9·45	13·73	10·79	14·82
Phosphate precipitated by chloride of calcium and ammonia	6·96	10·11	3·92	5·38

	34		35	36	
Water	958·8		1000	976·7	
Solid matter	41·20	100·00		23·30	100·00
Organic matter	34·68	84·18		17·46	75·94
Fixed salts	6·52	15·82		5·84	25·06
Phosphate precipitated by chloride of calcium and ammonia	2·15	5·21	8·86	1·79	7·68

The quantity of phosphate in the first analysis is very great, especially when the small proportion of saline matter in the urine is taken into consideration. In Analysis 32, the ash consists of as much as 73·63 per cent. of phosphates; in 33, 36·30 per cent.; and in 34, the proportion is further diminished to 32·93 per cent.

232. Urine in Delirium Tremens and Puerperal Mania.—*Analysis* 37. From a man, aged 36, on the fifth day of a slight attack of delirium tremens. He had had three severe attacks previously. Clear, high coloured; specific gravity, 1,015. The saline matter contained much sulphate, but not a trace of chloride.

Analysis 38. From a man, aged 31, with delirium tremens of a fortnight's duration. Acid; specific gravity, 1,020.

Analysis 39. From a woman with puerperal mania. Acid; specific gravity, 1,012.

Analyses.

	37		38	39
Water	959·32		1000·00	1000·00
Solid matter	40·68	100·00		
Organic matter				
Fixed Salts	6·30	15·48		
Phosphate precipitated by chloride of calcium and ammonia	2·93	7·20	7·66	3·40

233. Phosphates in the Urine in Health.—The following analyses show the varying quantity of the phosphates in the urine of a healthy man, 23 years of age. The large proportion of fixed salts depended upon the presence of much chloride of sodium.

Analysis 40. Passed at half-past 2 P.M., immediately after dinner. Clear, natural colour; acid; specific gravity, 1,015.

Analysis 41. Passed at 6 P.M. on the same day, after three hours' reading. Acid; specific gravity, 1,011.

Analysis 42. Passed at 2 P.M., immediately before dinner, on another day. Feebly acid; specific gravity, 1,022.

Analysis 43. Passed at half-past 6 P.M., four hours after dinner. Acid; specific gravity, 1,026.

Analyses.

	40		41	
Water	963·60		972·4	
Solid matter	36·40	100·00	27·6	100·00
Organic matter	14·75	68·00	19·89	72·07
Fixed salts	11·65	32·00	7·71	27·93
Phosphate of lime precipitated by chloride of calcium and ammonia	2·62	7·19	1·92	6·95

	42		43	
Water	943·80		936·80	
Solid matter	56·20	100·00	63·20	100·00
Organic matter	37·80	67·26	36·30	63·84
Fixed salts	18·40	32·74	22·82	36·16
Phosphate of lime precipitated by chloride of calcium and ammonia	2·40	4·27	6·22	9·84

234. Conclusions: The Phosphates in the Urine.—In the above analyses, can any relation be shown to exist between the symptoms present and the proportion of phosphoric acid? In some, there is, undoubtedly, an indication of such a relation; but in others, the proportion of phosphate is as great, although there was no evidence whatever of increased cerebral action or of inflammation. Without discussing the abstract question, I cannot think that the evidence at present obtained is sufficient to enable us to form a general conclusion. The inquiry is more difficult than it at first sight appears to be. Before any reliable conclusion can be drawn, we must determine how much phosphate is derived from the food, and how much from the oxidation of phosphorus. We have, then, to ascertain the proportion formed in the muscular system, as well as in the nervous structures. Dr. Hammond, who has carried on very many valuable researches upon subjects of this nature, has found that the phosphates in the urine are greatly increased after active exercise.

In any case of disease in which the excretion of an increased quantity of phosphates in the urine is suspected, we should ascertain—

1. The total quantity of phosphoric acid, in combination with alkalies, in the urine passed in the twenty-four hours.

2. The amount taken in the food within the same period of time.

To be more exact, the earthy phosphate in the urine should also be estimated, as well as that which passes off in the fæces.

I have not been able to ascertain that the quantity of phosphate excreted in the urine has ever been compared with the amount taken in the food, in diseases in which we should expect an increased disintegration of nervous tissue. Until experiments have been conducted so as to furnish us with positive data on this point, I do not think we are in a position to determine the question at issue. The results which have as yet been obtained are not sufficiently conclusive, as they fail to show even the total absolute amount

of mixed phosphate eliminated from the body in twenty-four hours. One can hardly suppose that, in cases in which the greatest possible amount of disintregation of nervous tissue was occurring, a very great increase in the phosphate would be observed, considering how very much of the total quantity is derived from the food; and of the comparatively small amount *formed* in the organism, a considerable proportion may originate in the muscular tissue. Very exact observations upon the in and out going phosphates have therefore to be made before we can hope to have the fact established conclusively.

I have ventured to occupy much time in the discussion of this question, and have gone more into detail than perhaps its importance, in the opinion of many practical men, demands. Still, when a long train of theories is constructed, the truth of which entirely depends upon the accuracy and correct interpretation of the experimental results from which it starts, it behoves us to examine rigorously into the nature of this foundation; for until the fundamental facts have been firmly established, we cannot allow ourselves to be led by the reasoning, however logical it may be; or receive the conclusions, however closely they may follow on the premises. While, therefore, I do not deny that increased nervous action may be associated with the formation of an increased quantity of phosphoric acid, which is eliminated in the urine, I think that the facts hitherto advanced in favour of this view are by no means conclusive; and I therefore hold that we are not yet in a position to form any theory upon the nature of the changes occurring in health or disease, in cerebral action, regarded from this point of view.

235. Variation in Earthy Phosphates.—The proportion of earthy phosphates does not seem to vary much in disease. Dr. Bence Jones has shown that, in cases in which the alkaline phosphates are increased, there is no corresponding increase in the proportion of earthy phosphates. Much of the earthy phosphate eliminated in the urine in health is doubtless derived from the food, but a certain proportion is set free in the disintegration of the tissues, especially the osseous tissues. An increase of earthy phosphate is observed in the urine in some very rare cases of disease, in which the earthy matter of the bones is absorbed (*mollities ossium*). In one acute case of this disease, Dr. Bence Jones ("*Phil. Trans.*," 1848) obtained indistinct evidence of the presence of chlorine, and suggests that, in

future, this substance should be searched for, as it may possibly be directly concerned in the removal of the earthy material from bones. This specimen of urine contained a peculiar substance of an albuminous nature. In 1,000 grains, there were 1·20 gr. of earthy phosphate; and the solid matter contained 1·18 per cent. The analysis will be found in Chapter XI.

236. Earthy Phosphates in the Urine: Mollities Ossium.—I have had opportunities of making analyses of the urine in two cases of mollities ossium. They were both well marked and fatal cases of the disease, and the specimens of urine were obtained shortly before death. The patients were quite bedridden, and the bones were so soft as to be readily indented by the finger.

Analysis 44.—This specimen of urine, from a woman suffering from mollities ossium, was sent to me by Dr. T. K. Chambers. The deposit contained oxalate of lime, with numerous stellate masses and separate crystals of earthy phosphate. Reaction, acid; specific gravity, 1,014.

Analysis 45.—From a case under the care of Dr. Greenhalgh. Morning specimen.

Analysis 46.—Night specimen.

Analyses.

	44		45		46	
Water	971·9		965·2		960·88	
Solid matter	28·1	100	34·8	100·00	39·12	100·00
Urea	5·0	17·7				
Extractives	10·22	36·3				
Fixed salts	12·88	45·81	14·44	41·49	5·25	13·42
Earthy phosphates precipitated by ammonia	1·185	4·21	·79	2·27	·4	1·02
Alkaline phosphates precipitated by sulph. magnesia and ammonia	1·13	4·21	·86	2·47	1·3	3·32
Triple phosphates filtered from the urine			·058	·16		

The large proportion of earthy phosphate in these analyses is a very interesting fact. In the first, the earthy actually exceeds the

alkaline phosphates; and in the second, it is nearly equal to it. In healthy urine, the alkaline phosphate usually amounts to from ten to fifteen times as much as the earthy phosphate. The inorganic salts, generally, are in considerable excess.

237. Excess of, as distinguished from, mere Deposits of Earthy Phosphate.—*Excess of Earthy Phosphate*, which has been shown to be so uncommon, must be carefully distinguished from the mere deposit of a certain amount in an insoluble form. The earthy phosphates very often form an insoluble deposit in the urine. The characters of these salts will be described under *Urinary Deposits.* It is hardly necessary to observe, that the deposit does not depend necessarily upon the excretion of an excessive quantity, but is often due to a change having occurred in some of the constituents which normally holds these salts in solution. A small quantity of deposit of earthy phosphates makes a great show in urine; and it is obvious that a very large proportion might be held in solution in the urine, and thus escape detection, unless an analysis were made. In the case just cited, the greater part of the earthy phosphate was in *solution* in the urine. It is common enough to find the deposit in cases of dyspepsia and overwork, and it is often spoken of as indicating the destruction of nervous matter. In these conditions, the urine often becomes neutral or slightly al[illegible], and this causes the precipitation of the phosphate. As b[illegible]ked, the quantity of the earthy phosphates is not perce[illegible] by those circumstances which influence the quantity [illegible] phosphate; and, although an excess [illegible] rable importance, its existence depen[illegible] rent nature.

[illegible] r caused [illegible] n in the qua[illegible] rine (Bö[illegible]

[illegible] be as[illegible] a Quan-[illegible] ease.—[illegible] estigation, [illegible] portan[illegible] ith regard [illegible] e foll[illegible] hour[illegible] ssed [illegible] and evening. [illegible] r three hours

Presence or absence of a deposit. If present, its microscopical characters. (Chapters XIII. *et Seq.*)

Presence of any of the substances to be described in Chapter XI. —albumen, colouring matter of bile, sugar, &c.

Estimation of the quantity of constituents in 1,000 grains of the mixed urine of twenty-four hours. From these data, the quantities passed in twenty-four hours are to be calculated.

	In 1,000 grs.	In 24 hrs.
Water	—	—
Solid matter	—	—
Organic matter	—	—
Saline matter	—	—
Urea	—	—
Uric acid	—	—
Free acid	—	—
Extractives, &c.	—	—
Alkaline phosphates, or phosphoric acid	—	—
Earthy phosphates	—	—
Sulphates, or sulphuric acid	—	—
Chloride of sodium, or chlorine . .	—	—

In particular diseases, it is very desirable to ascertain the quantity of one or two constituents removed in the twenty-four hours; and very much valuable information with regard to the nature of many diseases might be obtained by a number of careful and exact analyses of this kind. It is not necessary to fill up the above scheme in every case. In some, it would be desirable to know the amount of urea and uric acid with precision; in others, the amount of urea and sulphates. In diseases of the nervous system, the exact amount of alkaline phosphates passed in the twenty-four hours should be noted.

Before the investigation is commenced, the observer should determine exactly the points he wishes to ascertain, construct a table, and fill up the several columns daily from his analysis-book. Every analysis should be made in precisely the same manner, and careful notes of the case should be recorded daily. If possible, analyses of the urine should be made after the patient is restored to health; so that the quantity of the various constituents eliminated from the body in a state of health, may be accurately compared with the amount removed during the disease, and the patient should be weighed at intervals while under observation (§   ).

CHAPTER XI.

URINE IN DISEASE. SOLUBLE SUBSTANCES PRESENT IN URINE IN DISEASE WHICH DO NOT EXIST IN THE HEALTHY SECRETION. ALBUMEN—*Of Detecting the Presence of Albumen—Tests—Nitric Acid—Heat—Anomalous Results in Employing these Tests—Apparent Presence of Albumen in Urine which contains none—Phosphate resembling Albumen—Uric Acid resembling Albumen—Cases—Apparent Absence of Albumen in Urine which contains a large Quantity—Cases—Cause of the Precipitation of Albumen by Heat being prevented by a Trace of Nitric Acid—Other Tests for Albumen—On Estimating the Quantity of Albumen—Peculiar Substance in Urine allied to Albumen—Of the Importance of Albumen in Urine in a Clinical point of view—Importance of Examining the Urine of Persons proposing to Assure their Lives—Cases in which the Presence of Albumen is not associated with Disease of the Secreting Structure of the Kidney—On the Treatment of Cases of Albuminurea.* BILE—*Tests—Nitric Acid—Heller's Test—Pettenkofer's Test—Yellow Colour of the Cells, &c., in the Urinary Deposit—On the Clinical Importance of Bile in the Urine—Observations on the Treatment of Jaundice.*

239. Soluble Substances not present in Urine in Health.—I now pass on to the consideration of certain soluble substances not found in healthy urine, the presence of which is to be ascertained by the application of *chemical tests* to the urine. In many cases, however, our first suspicion of the existence of one or more of the substances now to be considered, is excited by certain peculiar characters affecting the deposit or the colour of the urine, or its peculiar smell or unusually high or low specific gravity may lead us to

suspect the presence of substances which we know would give rise to such characters. The matters referred to, being perfectly soluble in the fluid, cannot be detected by microscopical examination; but, in many instances, we may infer their presence from the microscopical characters of certain bodies in the deposit. Thus, the detection of epithelial cells of a yellowish colour would lead us to test the urine for *biliary colouring matter;* if casts were found upon microscopical examination of the deposit, we should test for *albumen;* if a certain kind of torula were present, we should have a suspicion that the urine contained *sugar.* In all cases, our conclusions must be verified by the application of appropriate tests, which will be presently considered.

The most important soluble substances present in the urine in disease, but absent in the healthy secretion, are *albumen*, *biliary constituents*, and *sugar*. The clinical importance of these is so great, that they deserve special attention.

Albumen.

240. Of Albumen in the Urine.—The occurrence of albumen has been regarded as a most important symptom ever since Dr. Bright showed that albumen was present in the urine in cases of disease of the kidneys, and pointed out the intimate connection between renal disease and dropsy. Albumen, it need scarcely be said, is absent from the urine of healthy persons, although now and then it may be detected for a short period of time in the urine of individuals who are not suffering from any serious or permanent derangement of the health. The presence of albumen must always be regarded by the physician as a point of serious importance, although at the same time, *per se*, it cannot be taken as evidence of the existence of any organic lesion, unless it has been clearly detected from day to day for a certain time. Many of the causes which give rise to the escape of serum from the vessels in other parts of the body, independent of disease, will determine its transudation through the walls of the renal capillaries, and, as a matter of course, it will be found in the urine.

To recognise with certainty the presence of a substance in the urine having so important a bearing upon the discovery and interpretation of certain morbid processes, as albumen, is obviously a

point of the utmost importance to the practitioner. In the examination of the urine of patients, certain tests are at once applied, in order to determine if this substance be present or absent. In the majority of cases, positive information is easily obtained; but occasionally an instance occurs in which, without great care, an erroneous conclusion is likely to be arrived at although the proper tests have been applied to the urine. As this question is one of very great practical importance, and of much interest, I propose to consider it at somewhat greater length than is usual in works devoted to the clinical examination of urine.

The reactions to which I shall refer are not imaginary, but have actually occurred to me. I have known instances in which albumen was stated to be *absent* when the urine contained a very large quantity; and other specimens have fallen under my notice, which, although they really *contained none*, yielded a precipitate having many of the characters of albumen. Let me, then, speak of the phenomena in regular order.

TESTS FOR ALBUMEN IN URINE.

241. Nitric Acid.—1. *Albumen is usually precipitated from its solution upon the addition of a few drops of nitric acid.* Heller recommended that the acid should be allowed to flow to the bottom of the tube containing the urine. In this manner, three strata are formed, the lowest stratum consisting of the pure acid, above which is the precipitated albumen, while the upper stratum consists of the fluid containing the albumen uncoagulated.

It must be remembered that two or three drops of nitric acid to about a drachm of albuminous urine in a test tube will produce a precipitate of albumen which will be *dissolved on agitation*, while, on the other hand, about half as much strong nitric acid as there is of urine will re-dissolve the precipitate of albumen, unless the quantity present be excessive. Albumen precipitated by nitric acid is *soluble* in *weak nitric acid* and in a considerable *excess of urine*, and it is also *soluble* in *strong nitric acid*. It is therefore necessary, in employing this test, to add from ten to fifteen drops of the strong acid to about a drachm of the urine suspected to contain albumen.

242. Heat.—2. *Albumen is also generally coagulated by the application of heat* (140° to 167° Fahr.). If very dilute, a higher temperature is required. The best way of testing urine by heat is the following:—An ordinary test-tube is about half filled with the urine, and is to be held between the finger and thumb by the lower part. Heat is applied to a point near the *surface* of the fluid; the tube being shaken a little at the time, to prevent the glass being cracked. The slightest precipitate cannot fail to be observed, as the fluid below remains perfectly unchanged. When urates are present, this plan is very useful, as we get three distinct strata; the upper one more or less turbid or milky, consisting of *coagulated albumen;* the next clear, in consequence of the *solution of the urates* at a temperature somewhat below that necessary for the coagulation of the albumen; and lastly, at the lower part of the tube, *the unchanged deposit of urates.*

243. Effect of Heat on Alkaline Albuminous Urine.—3. *If the solution of albumen be alkaline, no precipitate will be produced by heat. We are, therefore, generally directed to neutralise the alkali by an acid before heat is applied.* If excess of acid (ten to fifteen drops of the strong acid to a drachm of urine) be added, the albumen is, of course, precipitated in the insoluble form, without the application of heat.

244. Discrepancies.—Frequently specimens of urine are met with which exhibit one or more of the following peculiarities, tending to make us believe either that albumen is present when it is not, or to cause us to conclude that it is absent when the urine contains it.

1. Upon the application of heat, the specimen may become turbid, in consequence of the precipitate of phosphate. The reaction of the urine in this case would generally be neutral or feebly alkaline; but sometimes urine depositing phosphate on the application of heat is of a decidedly acid reaction (§ 161).

2. Upon the addition of nitric acid, the specimen becomes turbid, in consequence of the decomposition of the urates held in solution in the urine, and the deposition of *uric acid* in a granular state. If the acidified urine be boiled, it usually becomes clear, with the development of a pinkish or brown colour, consequent upon the decomposition of the uric acid and certain colouring matters.

3. Upon adding nitric acid to some specimens of urine of high specific gravity, an abundant precipitate of a crystalline character is produced. This consists of *Nitrate of Urea*, and is easily recognised by its crystalline character. It seldom appears immediately, and is hardly likely to be mistaken for albumen. Microscopical examination will at once determine the nature of the precipitate (§ 128).

4. After adding a drop or two of nitric acid to urine suspected to contain albumen, in order to render it distinctly acid, no precipitate is produced upon boiling, although a large quantity of albumen may be present. This is *constantly observed* in all specimens of albuminous urine, and shows the importance of never boiling urine suspected to contain albumen in a tube which may contain, by accident, a drop or two of nitric acid.

5. Cubebs, copaiba, and some other resinous substances, taken internally, are said to give rise to precipitates in the urine which are liable to be mistaken for albumen.

We have, then, to consider—

1. Cases in which a precipitate is produced in urine containing no albumen.

2. Cases in which no precipitate is produced, although the urine contains albumen.

1. A Precipitate Produced in Urine containing no Albumen.

245. Phosphate resembling Albumen.—The precipitate of phosphates is very readily distinguished from albumen by its solubility in a little acid. Upon the addition of a few drops of nitric acid, the turbidity produced by heat instantly disappears, and the solution becomes perfectly clear.

246. Uric Acid resembling Albumen.—When a precipitate of uric acid in a minute state of division is caused in consequence of the decomposition of the urates by nitric acid, its nature may be ascertained by allowing the mixture to stand for some time, when the minute granules gradually increase in size, and at length become crystals, the nature of which is at once recognised upon microscopical examination. In some cases, the crystals may be seen to form under the microscope. This precipitation of uric acid on adding nitric acid often leads to mistakes, and albumen is stated to be present in urine

which really does not contain a trace. Several cases of this precipitate have occurred to myself, and I have heard of many others in the practice of friends. It has happened in the wards of our hospital, that a precipitate produced by nitric acid has led the clinical clerk to state that albumen was present in the urine, when, upon being submitted to examination subsequently before the class, no precipitate could be obtained. The fallacy was explained as above.

Dr. G. O. Rees has met with urine affording this precipitate of uric acid on the addition of nitric acid, in cases of typhoid fever. Most of the instances which I have observed occurred in cases of liver-affection. I extract two or three as examples.

247. Specimens of Urine yielding a Precipitate resembling Albumen but composed of Uric Acid.—*Urine from a Patient suffering from large Hydatid Tumours of the Liver.* A small quantity of the urine was filtered, and, upon the addition of a little nitric acid, a precipitate was produced. After standing a little while, this was examined by the microscope, and found to consist of minute crystals of uric acid. These were dissolved upon the application of heat; but, as the solution cooled, they were deposited again in the form of much larger crystals.

A specimen of urine exhibiting the same peculiarity contained excess of urea. Upon the addition of half its bulk of nitric acid, the mixture became nearly solid, from the formation of crystals of nitrate of urea. The deposit in this instance consisted partly of urate of soda.

Another example, of which I have kept notes, occurred in a man aged 49, suffering from *rheumatic fever.* The urine was acid, specific gravity 1027, and contained much urate of soda. The practitioner who first saw the case boiled a portion of the urine. It remained clear; and he said, therefore, that it contained no albumen. A physician afterwards tested a portion of the same urine with nitric acid; and, finding that an abundant precipitate was produced, affirmed that much albumen was present. The deposit produced by nitric acid was found, by subsequent examination, to be dissolved by heat; and, when a portion was examined in the microscope, its true nature was decided by the presence of numerous uric acid crystals.

2. No Precipitate Produced in Urine containing Albumen.

248. Albumen *not coagulated by heat when a little nitric acid is present.* Upon the careful addition of a drop of nitric acid, the precipitate at first formed when the acid comes in contact with the urine, slowly dissolves as it descends towards the bottom. Upon boiling this *acidified solution, no precipitation of albumen will take place.* Upon the further addition, however, of nitric acid, the albumen is precipitated.

This reaction has often led to mistakes. Not unfrequently albuminous urine has been poured into a test-tube which contained a trace of the nitric acid remaining from some previous experiment; and, upon boiling the mixture under these circumstances, no precipitate of albumen has occurred. In some cases, two or three drops of acid are added, according to directions often given for the very purpose of acidifying the urine previous to boiling it. This fact must not be forgotten;—that *if a few drops of a dilute solution of nitric acid be added to a portion of albuminous urine in a test-tube, and the mixture boiled, no precipitate will be produced.* In fact, the addition of a little dilute nitric acid will *prevent* the coagulation of albumen by heat.

249. Explanation of this Reaction.—Dr. Bence Jones was, I believe, the first to offer an explanation of this fact, in a communication to the editor of the *Medical Gazette* (vol. xxvii., p. 289). Dr. Jones thinks that the solution of the albumen is owing to the formation of a nitrate of albumen which is soluble in a weak solution of nitric acid, even although boiling, but insoluble in a mixture of acid of moderate strength. Dr. Bence Jones has also shown that albumen is not always precipitated from very acid urine upon the application of heat.

From observations I have made, however, I have been led to conclude that the above result depends rather upon the decomposition of the phosphates by the nitric acid, and the consequent development of free phosphoric acid in which acid albumen is freely soluble. This view was confirmed by some experiments which I made some time since on the subject, and which have been many times repeated. A weak solution of albumen was treated with a few drops of chloride of calcium, and afterwards with a little ammonia. After having

stood for twenty-four hours, it was filtered. In this manner, any soluble phosphates present were removed. The solution was then tested as follows:—

1. Albumen was precipitated by the application of heat, or by the addition of nitric acid, as usually occurs.

2. A very small quantity of dilute nitric acid did not prevent the coagulation of the albumen by heat.

3. After the addition of a few drops of phosphoric acid, the fluid no longer coagulated upon being boiled.

Some of the same solution as the above, which had not been treated with chloride of calcium and ammonia, afforded the same results upon the application of the tests as other albuminous solutions. A few drops of a weak solution of nitric acid, or a little phosphoric acid, prevented the precipitation of the albumen by heat. The addition of phosphoric acid to an albuminous solution, or a soluble phosphate and a little nitric acid, prevented the precipitation of the albumen by heat.

These results, therefore, led me to conclude that a trace of nitric acid prevents the coagulation of a moderately strong solution of albumen by heat, in consequence of decomposing the phosphates and setting free phosphoric acid, in which the albumen is soluble. When, however, excess of nitric acid is added, its action predominates over that of the phosphoric acid, and the albumen is precipitated.

At the same time, it must be admitted that there are several facts connected with the behaviour of weak solutions of albumen with acid, and under the influence of heat, which are not satisfactorily explained; and forms of albumen having different reactions are from time to time met with. The whole subject requires further careful investigation.

250. Other Tests for Albumen.—Albumen is precipitated from its solutions by alcohol, alum, and many metallic salts, as those of lead, mercury, copper, and silver. The presence of grape sugar prevents albumen from being precipitated by sulphate of copper and liquor potassæ. The mixture forms a dark blue solution. In its turn the presence of the albumen prevents the reduction of the oxide to the state of sub-oxide when the mixture is boiled (see test for sugar). Bichloride of mercury is employed as a test, and ferro-

cyanide of potassium precipitates a solution of albumen to which *acetic acid has been added.* These salts will, however, produce precipitates in solutions of other substances allied to albumen.

251. On Estimating the Quantity of Albumen in Urine.—The quantity of albumen varies much in different cases, sometimes amounting to a mere trace; while, in other instances, a proportion not much inferior to that present in serum has been met with. In one case as much as 545 grains were excreted in 24 hours (Parkes). In order to estimate the quantity of albumen, it is only necessary to add a little acetic acid, by which any combination of albumen with alkali is decomposed, and heat the urine in a water-bath to a temperature of 194°, or until it boils. The precipitate is to be collected on a weighed filter, well washed, dried, and weighed. The albumen always contains a small quantity of earthy salts, which are obtained by incineration. The residue must be deducted from the weight of the dried precipitate.

Albuminous Urine, from a patient with acute inflammation of the kidney. The deposit contained numerous granular casts, but no fat-cells were present; specific gravity, 1015; acid. The albumen coagulated by heat and nitric acid.

Analysis 47.

		In 100 parts of solids.
Water	952·00	
Solid Matter	48·00	100·00
Urea	13·052	27·19
Albumen, mucus, and uric acid	19·204	40·00
Extractives	12·864	26·80
Alkaline salts	2·784	5·80
Earthy salts	·096	·20

252. Peculiar Forms of Albumen.—Scherer describes a variety of albumen which is only imperfectly coagulated by heat. It is possible, however, that many of the peculiar reactions met with from time to time, depend upon the presence of other substances dissolved with the albumen, rather than upon any peculiar properties of the albumen itself, or the existence of a variety of this substance. The reaction of different solutions of albumen is a subject well worthy of minute investigation.

258. New Substance allied to Albumen.—Dr. Bence Jones obtained a new substance allied to albumen from the urine of a patient (under the care of Dr. Watson and Dr. MacIntyre) suffering from mollities ossium. The urine was slightly acid; specific gravity, 1034·2 (*Phil. Trans.* for 1848, p. 55). The deposit consisted of phosphate of lime, oxalate of lime, and cylinders of fibrine. Phosphates were precipitated by heat; but the urine was cleared by adding a drop of acid. No precipitate was produced by nitric acid; but, after being heated and left to cool, it became solid. The solid material was redissolved by heat, and precipitated again when the mixture became cool. On some days, the urine coagulated by boiling; on others, prolonged boiling produced no change. A specimen, which did not coagulate by boiling, was carefully examined. It was acid; specific gravity, 1039·6. It contained much urate of ammonia, phosphate of lime, and oxalate of lime. The urine contained—

		In 100 parts of solids.
Water	890·72	
Solid matter	109·28	100·00
New substance	66·97	61·28
Urea	29·90	27·36
Uric acid	·96	·87
Earthy phosphate	1·20	1·18
Chloride of sodium	3·83	3·50
Sulphate of potash	2·10	1·92
Alkaline phosphate	4·45	4·07

The new substance was precipitated from the urine by alcohol, well washed, and ultimate analyses were made. It contained 1·09 per cent. of sulphur, and ·20 per cent. of phosphorus. This substance is the *hydrated deutoxide of albumen.* It was soluble in boiling water, and the precipitate produced by nitric acid was redissolved by heat, and it formed again as the mixture cooled. A similar substance occurs in small quantity in pus, and in the secretion from the vesiculæ seminales. The urine contained 66·97 parts per 1000 of this substance—an amount equal to the quantity of albumen in the blood. The patient was passing about thirty-five ounces of urine daily, which would contain upwards of 1000 grains, or more than two ounces of this new material.

Dr. Bence Jones recommends that this substance should be

looked for again in acute cases of mollities ossium. He suggests that the reddening of the urine upon the addition of nitric acid might lead to its detection.

254. Of the importance of Albumen in the Urine in a clinical point of view.—The presence of albumen in the urine may be due to—1, temporary or permanent changes in the secreting structure of the kidney itself; or, 2, to changes occurring irrespective of the kidney, as alterations in the character of the blood, pressure of tumors upon the cava, &c. (§ 256).

ALBUMEN IN THE URINE DEPENDENT UPON ACUTE OR CHRONIC CHANGES IN THE KIDNEY.

In the majority of cases, in which the urine contains a very large quantity of albumen, and especially if the urine be of specific gravity of 1020 or higher, and of a dark brown colour or smoky hue, caused by the action of the acid of the urine upon the colouring matter of the blood, the inference will be that the case is an *acute one*, and that this large quantity of albumen has not been passing away from the kidney for any length of time. In very many of these cases blood is present. By far the majority of acute cases recover if the patients are placed under favourable circumstances. In some instances, however, the circulation through the kidney becomes more and more obstructed; the urinary constituents accumulate in the blood and seriously impair the various actions going on in the body, and especially affect the nervous system; and death results, probably preceded by coma and sometimes by convulsions (*see* p. 68, also my "*Archives*," Vol. II., p. 286). Occasionally pus is formed in considerable quantity in the uriniferous tubes. Sometimes the acute stage passes off, and the albumen, although it diminishes in quantity, does not entirely disappear from the urine, and the acute attack afterwards proves to have been the commencement of chronic kidney-disease.

In chronic fatty degeneration of the kidney there is often also *a very large quantity* of albumen, but the urine is *pale* and of low specific gravity. The history of the case, the appearance of the patient, the symptoms present, and the microscopical characters of the deposit (*see* "casts") render it almost impossible to mistake a case of chronic fatty degeneration for one of acute inflammation of

the kidney caused by cold, or following scarlet or other eruptive fever. For the microscopical characters of the urine, which are exceedingly distinctive in these cases, see Plates XV., XVI., and XVIII., of the "*Illustrations of urine, urinary deposits, and calculi.*"

If the quantity of albumen be small, amounting merely to milkiness or opalescence when heat is applied, or nitric acid added to the urine, and especially if the urine be pale and of specific gravity 1012 or lower, we should suspect that the lesion giving rise to the escape of the albumen was chronic, and probably depended upon contracted kidney. If the proportion of urea to the other constituents of the solid matter were large, we should form a more favourable opinion than if the percentage of urea in the solid matter were very much less than in health. In the latter case, a great part of the renal structure would probably be involved; but, in the former, there would be reason to think the disease had only affected a certain number of the secreting tubules. There are, however, some exceptions to these general statements. Patients have passed small quantities of albumen in the urine for many months, and it has afterwards disappeared. In other cases the progress of the disease is exceedingly slow. I have known a man pass urine of the character above mentioned for upwards of twelve years; and I believe that this might go on for twenty years, or even longer, the patient perhaps dying at last of some other malady. It must, however, always be borne in mind that such persons are more likely to suffer from exhausting influences, cold, fatigue, &c., than others.

255. Importance of Examining the Urine of Persons Proposing to Assure their Lives.—It is very important that the medical officers of Life Insurances should be aware that there are many instances of persons having chronic disease of the kidney, who are not themselves aware of it. Neither is there in many of these cases anything in the appearance or history of the person that would cause the physician to suspect the true nature of the case. The discovery of albumen in the urine, or of casts in the deposit, is sometimes the only point which leads the practitioner to a correct knowledge of the doubtful nature of the life. Now, if one of these persons experienced a severe attack of catarrh, his life might be endangered; and exposure to cold would be very likely to set up acute inflammation of the kidneys, already impaired by disease, and

might thus prove fatal. The only way to discover such a condition, is to institute a careful examination of the urine in every case; but, to carry this out practically, it must be confessed, there are many difficulties, and often objections on the part of the proposer. If, however, the medical referee should have the slightest reason for suspecting the existence of renal disease, he is quite justified in insisting upon the necessity of examining the urine.

A microscopic examination of the deposit in the urine will throw much light upon almost all cases of albuminuria, and enable us to diagnose the condition with much greater precision than is possible from a mere chemical examination. We cannot, however, be too cautious in arriving at a *prognosis* in these cases. Every circumstance connected with the individual case must be carefully considered, and the state of nutrition, the progress the disease has made in a given time, the state of other organs, the constitution of the patient, his circumstances, temperament, &c., must be passed in review. The practitioner should always express a very guarded opinion as to the probable duration of life, for under favourable circumstances life may be prolonged for many years, while an attack of pneumonia, or fever, or even common catarrh, occurring at any time, might prove fatal, although the patient was considered by himself and by his friends to be in good health at the time of the attack. I have seen apparently slight cases die within a very short period of time, and very severe cases of disease, accompanied with general dropsy, and ascites, with great prostration, and diarrhœa, which were not expected to live a week, rally, recover from the dropsy, and live for some years afterwards, in the enjoyment of far better health than the most hopeful practitioner would have anticipated.

Albumen in the Urine not dependent upon Renal Disease.

256. Cases in which the Presence of Albumen is not associated with Disease of the Secreting Structure of the Kidney.— Albumen is always found in small quantity in urine containing pus. We shall therefore meet with it in cases of inflammation of the kidney (pyelitis), and in cases of inflammation of the bladder and of the mucous membrane of the urinary organs generally. Whenever blood is present in the urine albumen is detected; for, if blood-

corpuscles escape from ruptured capillaries, a certain quantity of serum must at the same time pass through the fissures. The colouring matter of the blood is sometimes passed in urine in a state of solution; but in this case, also, a certain quantity of albumen is present.

Dr. Bence Jones detected albumen in the urine of a patient who passed spermatozoa. The urine passed in the morning contained spermatozoa and albumen. The evening specimen contained neither. On a subsequent examination, no albumen could be detected.

I have detected albumen in many cases of pneumonia during the period of hepatisation of the lung. It is present, also, in the specimens of urine first passed after the period of suppression in cholera. In some cases of acute rheumatism with pericarditis it is observed; and it has been occasionally detected in continued fever. In puerperal fever it is often met with, and in puerperal convulsions it is almost constantly present. Dr. Lever found that it was absent in only one case out of fifty. The pressure of the gravid uterus is probably a cause of the albuminous urine met with in some cases of pregnancy, but it cannot always be referred to the same cause, for it sometimes occurs at an early period of pregnancy, when the uterus is too small to exert much pressure. Dr. Tyler Smith considers that it is to be accounted for by an influence exerted upon the nerves, in those cases in which it is not connected with organic disease. Out of 112 specimens of urine from pregnant women, Dr. H. Van Arsdale and Dr. Elliott only found albumen present in two instances. ("*New York Journal of Medicine*," 1856).

After intermittent fevers albumen frequently escapes in the urine. In cases in which any physical impediment to the return of blood in the emulgent veins or inferior cava exists, and in some cases of obstructed portal circulation, as in cirrhosis of the liver, traces of albumen may be detected in the urine. In anæmia, and in cases of dropsy depending upon an impoverished state of the blood, albumen is often passed. Sometimes a large quantity of blood extractive matter is also present. After long continued hæmorrhages, when dropsy occurs, we not unfrequently find albumen in the urine. In these cases it does not depend upon kidney-disease, but upon the state of the blood. Just as serum escapes from the capillaries of various tissues of the body, it is prone to transude through the renal vessels. Lastly, in persons who have suffered for many years from

affections which produce alterations in the capillary walls, albumen may pass off in the urine; and towards the termination of exhausting diseases it is frequently present.

In cases in which the presence of albumen depends upon obstruction to the circulation in the kidney, the impediment may be *functional or temporary*, or it may be *organic and permanent.* As examples of the presence of albumen depending upon temporary congestion, may be adduced certain cases of pneumonia and cholera, cases of acute dropsy, and of dropsy consequent upon scarlatina, with many others. Fatty degeneration and chronic nephritis may be brought forward as instances of structural disease, which *permanently affects* the circulation of the blood through the kidney, so as to cause albumen to transude through the capillary vessels.

In the majority of cases, the vessels of the Malpighian tuft doubtless form the precise seat of the escape of albumen; but there are reasons for believing that albumen sometimes passes from the capillaries surrounding the convoluted portion of the uriniferous tubes, and in some instances from those in contact with the straight portion. ("*Archives of Medicine,*" Vol. I., p. 300.)

In most cases in which albumen occurs in the urine, casts of the uriniferous tubes are also found; for with the serum a certain quantity of coagulable material transudes or is found in the tube, and this becomes solid while it lies in the tube, of which it thus takes a mould, and entangles in its meshes any loose bodies, as particles of epithelium, &c., which may happen to be in the tube at the time. In the first series of cases alluded to, casts are often absent, or, if formed, they are perfectly transparent. On the other hand, where the structure of the kidney is altered, the casts often afford evidence of the nature of the lesion. This part of the subject will be considered in Chapter XIV. Albumen is, however, often present without any deposit, so that for its detection we must rely solely on chemical tests.

Treatment of Albuminuria.

257. On the Treatment of Cases of Albuminuria.—It is not possible, in a work of this kind, to enter fully into the treatment of cases in which albumen is passed in the urine; but it may not be altogether useless to offer a few brief observations upon the general

principles which should be carried out. The subject may be thus divided:—

1. Acute cases in which the kidney is affected.
2. Chronic cases in which the kidney is affected.
3. Cases in which the kidney is not affected.

Treatment of Acute Albuminuria.—The treatment of the first class of cases is now well understood. Cases of acute dropsy, from exposure to cold and wet; dropsy after scarlatina, measles, or other eruptive fever; and all cases in which the kidney is acutely affected, so that but a small quantity of water containing a large quantity of albumen is secreted—come under this head. In all such cases the kidney requires *rest*, and the physician endeavours to excite the action of those emunctories by which urinary constituents may be eliminated—these are the skin and the intestinal canals. Hot air baths, sudorifics, and purgatives (compound jalap powder, elaterium, or gamboge), often give great relief in this class of cases. At the same time, cupping over the kidneys is often required to relieve the intense local congestion. When the acute symptoms have subsided, and the water has increased in quantity, while the albumen has diminished, especially in cases in which much blood has been carried off in the urine, tonics should be given; but by far the most valuable remedy I have employed under these circumstances, as well as in many chronic diseases of the kidney, is the tincture of the sesquichloride of iron.

But, from time to time, cases of acute inflammation of the kidney are seen, in which the acute symptoms do not pass off as rapidly as usual. Instead of the dropsy disappearing within a week or a fortnight, it persists, or the swelling becomes greater, and the urine does not increase in quantity, or lose the large proportion of albumen it contains. Many of these cases depend upon the general state of the health, and, no doubt, are due to the poor state of the blood, which renders absorption impossible. Often we shall find the digestive organs out of order, and the greatest benefit results from the use of pepsin (§ 315) and dilute hydrochloric acid, as well as the tincture of sesquichloride of iron. The appetite improves, the blood becomes more healthy, and then the effused serum is soon absorbed. In one patient suffering from acute dropsy (W. S., Vol. III., p. 7), each leg measured *eighteen inches* in circumference a month after the attack had commenced, and the effusion seemed to be increasing. In a month after,

the treatment had been altered as above, the circumference of the legs had diminished to *thirteen inches*, and in this short time several pints of serum must have been removed from the areolar tissue of the body generally. The quantity of urine increased from about twenty to fifty ounces in the twenty-four hours.

Treatment of Cases of Chronic Albuminuria. This condition may depend upon several different morbid changes. The two most common are fatty degeneration and chronic contraction. Many cases of the former condition go on for years. I know one case of a patient who has for fifteen years been suffering from fatty kidney, passing a considerable quantity of albumen during the whole period. Although his general health is affected, and there is some degree of dropsy, there are no urgent symptoms. The disease must, of course, terminate fatally, but in these cases we must be very cautious in giving an opinion as to the length of time a patient is likely to live. I have seen several cases of bad general dropsy, depending upon fatty kidney and chronic contraction, rally and go on for years after it was supposed the disease would have terminated fatally. Under favourable circumstances, it appears the disease makes very slow progress, and, in many cases, there is reason to believe that several of the uriniferous tubes of some or both kidneys are in a tolerably sound state. In treating a case of fatty kidney, attention must be paid to the general state of health. Nutritious diet, plenty of fresh air, the sea side or a sea voyage, often produce marked benefit. Of medicines, the tincture of sesquichloride of iron is among the most valuable, but it should be continued for many months at a time. Glycerine is a remedy which improves the health in some of these cases. Where the stomach is irritable at an early period of the disease, alkalies and hydrocyanic acid afford relief; but pepsin is of great value in some cases, and at once relieves the dyspeptic symptoms. Towards the close of many of these cases vomiting is often the most distressing symptom, and it is most difficult to relieve or control it. Creasote, ice, and other remedies may be tried, but the food should be given in tea-spoonfuls only at a time.

Many cases of fatty degeneration of the kidney seem to be connected with the scrofulous habit, and in the early stages of the disease the general treatment is the same in both conditions. Although, from the nature of the disease, some might be inclined to deny patients fatty matter, in the early stages cod liver oil, and

everything likely to improve general nutrition, is advantageous. The fatty matter found in the fatty kidney is not ordinary fat, like that existing in adipose tissue, but it is very rich in cholestissue, as is the case with the fatty matter found in all tissues undergoing what is termed fatty degeneration. Tubercle also contains cholestissue. We must not, therefore, deny to patients suffering from this malady food rich in fatty matter, on the ground that too much fat is being formed in the kidney. If nutrition be improved, the tendency to the morbid change will diminish. I doubt if fatty matter in the food exerts more influence on the kidney in these cases than it does upon the liver in cases of phthisis. We should certainly act upon a wrong principle if we discarded the use of fats in the latter malady because there was a fear of promoting the formation of fatty liver.

The next class of cases of chronic albuminuria, in which the kidney is structurally affected, are of a very different character. In these the kidney gradually diminishes in size, while its structure becomes very firm and dense (*See* p. 67). This form of renal disease has been termed gouty kidney, chronic nephritis, contracted kidney. The disease is closely allied to cirrhosis of the liver, and, like it, consists of a gradual contraction and condensation of the secreting structure. At first there is in both maladies engorgement of the vessels, and, consequent enlargement of the organs; but this state is followed by a gradual wasting process. The disease commences in the cells, and the pathological changes observed in the organs after death are the consequence of changes occurring in the cells. The cells become smaller, and the functional activity of many gradually ceases; the vessels waste, and at last the organ seems to be mainly composed of "connective tissue." I have shown that in fact, the so called "connective tissue corpuscles" represent portions of wasted uriniferous tubes and cells. This contraction depends not upon inflammation and change occurring in effused lymph, but upon the wasting and condensation of the normal structure. This form of renal disease results most commonly from drink; but I have seen small puckered and contracted kidney in persons who have never indulged in alcoholic liquors at any period of their life. The same observations apply equally to cirrhosis of the liver.

In contracted kidney, the quantity of albumen in the urine is often so very small as to be sometimes overlooked. If the nature of the change which is occurring in the kidney be borne in mind,

the practitioner will at once adopt the appropriate treatment:—diet that tasks the kidney as little as possible, and due attention to the general health. Tonics and iron are useful, but it must be admitted that in many of these cases we must give diuretics, and diurectics act most admirably sometimes. Compound decoction of broom, compound spirits of juniper and digitalis, and even cantharides may be given cautiously, and in some cases with great benefit.

Treatment of albuminuria when the kidney is not affected.— Lastly, as to the treatment of those cases of albuminuria in which there is no renal disease. After exhausting hæmorrhages, in low conditions of the system, after low fevers, in some cases of phthisis and chronic bronchitis, and in some other conditions, albumen passes off in the urine. In some of these cases, dropsy is present, in others there is scarcely the slightest puffiness to be detected in any part of the body. Every effort must be made to improve the general health, and iron is especially valuable in these cases. I need scarcely say there is no indication for the use of remedies specially influencing the kidney.

It is unnecessary to allude to the treatment of cases depending upon temporary internal congestion, as occurs in pneumonia and cholera, nor to those in which the escape of albumen depends upon pressure, exerted by the gravid uterus, or by internal tumors upon the veins.

There are some other cases of albuminuria which have not been alluded to, as for example, cases of chylous urine, and cases of temporary congestion of the kidney, but these will be discussed in the proper place. For further and more detailed information, the reader is referred to the works of Dr. Johnson, and Dr. Basham.

BILE.

When much bile is present in urine, it gives to the secretion a very dark yellow colour, which is even more distinct when thin layers are placed upon a perfectly white surface, as on a plate, than where a considerable bulk of urine is examined. This arises from the presence of the colouring matter, which has received the name of *biliverdin.* It may be completely removed from any solution containing bile by causing it to filter through a layer of charcoal. The presence of bile in urine is commonly observed in cases of

jaundice. From some cause or other, as from pressure upon, or obstruction of, the common duct, bile, after it has been secreted, is partly or entirely prevented from escaping into the intestine. The gall-bladder and large and small ducts soon become distended by the accumulation of the secreted bile, which, finding no escape, is reabsorbed. Some of its constituents pass into the blood, and are partly deposited in the tissues and partly carried off in the urine. That scarcely any bile passes into the intestine in many cases of jaundice, is proved by the pale colour, offensive odour, and clay-like consistence of the fæces.

Several tests have been proposed for the detection of bile in urine. The efficacy of some of these tests depends upon a change being produced in the colouring matter; that of others upon alterations of the resinous acids.

For Detecting the Colouring Matter of the Bile.

258. The Nitric Acid Test.—This may be applied in two ways: (*a.*) A few drops of the biliary urine are to be poured upon a white plate, and a drop of nitric acid allowed to fall upon it. As the acid gradually mixes with the surrounding fluid, a play of colours, commencing in green, passing through various shades, and terminating in red, will be observed.

(*b.*) A portion of the urine is to be placed in a test-tube, and treated as before. If much bile be present, a bluish-green colour at first appears. This is succeeded by various shades, until the play of colours terminates in red.

259. Heller's Test consists in adding to the suspected urine a few drops of a solution of albumen, and, after agitation, a little nitric acid. If the colouring matter of bile is present, the flocculi of albumen which are precipitated will possess a dull green or bluish colour.

Not unfrequently, the albuminous flocculi, when thrown down by nitric acid in urine destitute of bile, are more or less coloured in consequence of the action of the nitric acid on the colouring matter of the urine (uroxanthine). The colour is sometimes reddish, sometimes bluish. This change is not unfrequently observed

in albuminous urine; and Dr. Basham considers it a condition of very unfavourable significance, and states that he has met with it most frequently in the acute forms of renal disease ("*On Dropsy connected with Disease of the Kidneys*," p. 48). This reaction must not be mistaken for that dependent upon biliary colouring matter.

260. Colour of Phosphates.—After exposing urine to the air for a day or two, crystals of triple phosphate are formed, as is well known. If bile pigment be present, these crystals have a yellow tinge. Hassall ("*The Urine*," p. 27.)

261. Acetate of Lead.—In urine containing bile, the precipitate produced by the addition of acetate of lead has a yellowish colour.

262. Evidence of Bile obtained by Microscopical Examination of the Deposit.—If the urine contain any epithelial cells from the kidney, as is usually the case, microscopical examination of the deposit will at once show the presence of bile, as the cells have a bright yellow tinge. The existence of this tinge proves conclusively the presence of bile colouring matter; but its absence cannot be regarded as satisfactory proof of the urine being free from bile. In cases of kidney disease, when bile is present in the urine, the casts, as well as the cells they contain, when examined in the microscope, are seen to have a deep yellow tinge. Cells of vaginal and bladder epithelium even, are often intensely coloured in cases of jaundice. In one case of jaundice, associated with wasting of the liver, I found a vast number of dumb-bells of oxalate of lime in the urine. These dumb-bells were coloured of an intense yellow colour, but the octohedral crystals, which were also present in considerable number, were colourless.

The five tests just described enable us to detect only the colouring matter of the bile.

For Detecting the Biliary Acids.

263. Pettenkofer's Test.—If albumen be present, this must first be coagulated, and separated by filtration. About a drachm of the urine is to be treated with about two-thirds of its bulk of strong sulphuric acid, which is free from sulphurous acid, the acid being added drop by drop, to prevent the temperature rising much above

100°; a piece of sugar, about the size of a large pin's head, or a drop or two of syrup may now be added to the mixture, and in the course of a minute or two a violet tinge will occur if bile be present. This test is not perfectly satisfactory, since it is very easy to obtain a reddish colour by the action of the acid upon the sugar if albumen and no bile is present; moreover, oil of turpentine, oil of lemons, and of cloves, with other substances, yield similar results. In all these cases, however, the colour is not bright like that produced by the acids of the bile. The action of the sulphuric acid on the sugar alone produces a brownish-red, but this cannot be mistaken, as the colour is very different from that developed by bile. I recommend everyone to become familiar with these colours, by going through the experiments for himself by daylight with a diluted solution of bile.

264.—Hoppe's Method.—The method of applying this test has been modified by Dr. Felix Hoppe, whose plan answers exceedingly well, and is so delicate that the smallest quantity of biliary acid can be detected with the greatest certainty. The urine suspected to contain bile is to be treated with excess of milk of lime, and boiled for half an hour. The clear fluid obtained by filtration is evaporated nearly to dryness, and then decomposed with excess of strong hydrochloric acid. The mixture is to be kept boiling for half an hour, and the acid is to be removed from time to time, to prevent the spurting which would occur if the mixture became too concentrated. When completely cold, the mixture is to be diluted with from six to eight times its volume of water. The turbid solution is to be thrown on a filter, and the resinous mass washed until the water runs through quite colourless. The insoluble mass is next to be dissolved in spirit containing 90 per cent. of real alcohol, decolourised with animal charcoal, again filtered, and evaporated to dryness over a water-bath. The yellowish resinous residue is pure *choloidic acid.* By warming it, it emits a peculiar musk-like odour. It is to be dissolved in a little caustic soda and warm water, a little sugar added, and three drops of concentrated sulphuric acid are allowed to fall slowly into the mixture. The resinous acid is at first precipitated; but afterwards, the flakes adhering to the glass are slowly dissolved by the addition of more sulphuric acid, and a perfectly clear fluid, of a beautiful dark violet colour, is produced. (Virchow's "*Archiv.*,"

Vol. XIII.; "*Archives of Medicine*," Vol. I., p. 346; Abstract of Kühne's Paper on "*Icterus*," by Dr. G. Scott.)

265. On the Clinical Importance of Bile in the Urine.— The consideration of this question involves the discussion of the pathology of jaundice, a subject upon which there is the greatest difference of opinion in the present day. Indeed, observers are not even agreed as to the mere structure of the healthy organ; and Henle has very recently written a paper confirmatory of the view of Dr. Handfield Jones, who maintains that the liver-cells are situated outside the ducts, and are concerned rather with the formation of amyloid matter or sugar, than with the production of bile. Frerichs again in his work on diseases of the liver does not discuss the structure of the healthy organ, but seems to consider that the liver-cells lie between the capillaries in connective tissue, and have no direct connection with the ducts. In his numerous drawings he has almost ignored the existence of the ducts. He has described and figured in cirrhosis as "bindegewebe" (connective tissue), cell-containing-tubes as distinct, in properly prepared specimens, as any uriniferous tubes, and has omitted to represent the relation of the cells to the ducts in one single instance. Until these simple questions of elementary anatomy be decided, it is impossible that we can agree in opinion upon the altered action of so elaborate an organ as the liver in disease. Professor Frerichs' injections have been made with opaque injection, a mode of preparation which renders the demonstration of the healthy structure, or of the changes which have occurred in disease, impossible.

I possess many specimens of the liver injected with transparent fluid ("*Archives*," Vol. I.), which prove most conclusively, that the liver-cells lie in tubes continuous with the ducts. This view has now been received by Kölliker and others. The bile formed by the cells passes directly into the ducts, and is carried away by the larger ducts. In jaundice there are impediments to its escape from the large ducts outside the liver, or from smaller ducts within the organ. In either case the bile accumulates, the ducts become stretched, a certain quantity passes through their coats, and is taken up by the bloodvessels, or what is more probable, is absorbed by the numerous lymphatic vessels, ramifying in the portal canals, and in the transverse fissure of the liver.

It is, however, held by Dr. Budd, that jaundice may result—1. From *obstruction to the escape of bile* from the liver after it has been formed, and,—2. From what is termed *suppressed secretion*, in which case it is supposed that the substances, which should be separated from the blood and converted into bile, remain in the circulation. Frerichs, Kühne, and others, have brought forward arguments opposed to this view, but it has recently received support from the observations of Dr. Harley, who observes that certain constituents (biliverdin, cholesterine) of the bile, are produced in the blood, and are only separated, and not *formed*, by the liver, while there are other constituents (glychocholic and taurocholic acids) which are actually formed by the liver. From this he argues, that where the colouring matter is alone found in the urine, the case is one of jaundice from *suppression*, while, if the biliary acids are present, it is clear that these substances must have been *formed* by the liver, reabsorbed into the blood, and excreted in the urine, and the case, therefore, arises from *obstruction.*

It must, however, be borne in mind that the proportion of biliverdin and cholesterine in bile is very small, and that although biliverdin can be formed from the colouring matter of the red blood corpuscles, and might tinge the tissues and the urine, no one has shown that it is ever produced in sufficient quantity to give rise to the intense general staining often seen in jaundice. There are facts in favour of the view that colouring matters as well as the resinous acids are actually formed in the liver. Moreover, it is difficult to conceive, that a large and important organ like the liver, can cease to perform its functions for three weeks or a month, without giving rise to the most serious constitutional symptoms, and without itself suffering most serious alterations in structure. Nor have those who support the *suppression theory* attempted to explain what becomes of the large quantity of material, which would, under other circumstances, have undergone conversion into biliary acids.

On the other hand, in certain cases of cirrhosis, where there is a most positive and gradual wasting of the secreting structure of the liver, there is no jaundice. How is it that the biliverdin, formed in the blood, does not tinge the tissues in these cases? Nor are we justified in placing the same reliance upon Pettenkoffer's test when applied to the urine, as some observers are inclined to do. I cannot feel satisfied that in those cases in which I fail to obtain indications of

the resinous acids, that they are *really* absent. Kühne has detected the presence of bile acids in many specimens of icteric urine, by following Dr. Felix Hoppe's method (§ 264). Although all recent observers, who have studied this subject, admit that the detection of the biliary acids is most difficult and requires the greatest care, Dr. Harley seems to rely upon the ordinary Pettenkofer's test to distinguish two classes of cases of jaundice. Kühne's observations have quite disproved Frerichs' theory, that the biliary acids were converted into bile-colouring matters in the blood, and the statement of Frerichs and Städeler, that bile-colouring matter and bile acids *never* appear together in the urine, has been shown to be erroneous. For full information upon this subject the reader is referred to an abstract of Kühne's observations by Dr. Scott. ("*Archives*," Vol. I., p. 342.)

It seems to me that the view that in certain cases of jaundice there is suppression of the action of the liver, that the liver does not produce bile, and that no biliary acids are formed, is opposed to very many facts, and I have been led to incline towards the view that in all cases of jaundice the bile has been formed by the liver cells, and has been reabsorbed after its formation, and perhaps much of it again excreted in an altered form by the intestines. It is easy to conceive that the relative proportion of the biliary acids and colouring matters produced, may be very different in different cases—that the quantity of the acids formed, may vary greatly—that their composition may be affected—taurocholic acid being produced instead of glycocholic acid (Kühne)—that the quantity of blood corpuscles disintegrated by the presence of bile compounds in the blood—and that other chemical derangements may be caused without the action of the liver *cells* being suspended.

266. On the Treatment of Cases of Jaundice.—Cases of jaundice, which occur so commonly during the summer months, and are not connected with organic disease, require but very simple treatment. The jaundice usually lasts for a period varying from a fortnight to five or six weeks, and then gradually disappears. The pathology of these common cases is not at all understood. In many there is scarcely any constitutional disturbance, although the urine is very dark-coloured and sometimes contains biliary acids, and the fœces are perfectly colourless. Gentle laxatives and small doses of

hydrochloric acid or ammoniacal salts seem to do good, but the remedial measure in which I have the greatest confidence consists in mild counter-irritation over the liver. Even the application of cold wet cloths for half an hour now and then will relieve the pain, sense of fulness, or uneasiness, about the hepatic region; but rags steeped in equal parts of strong hydrochloric acid and water applied for half an hour daily form the best application. This application, which I learned from Dr. Blakiston, is of great service, not only in actual jaundice, but in cases of temporary biliary derangement generally. The acid may, perhaps, act through the cutaneous nerves, by exciting the biliary ducts and gall bladder to contract. It also causes action of the colon. Small doses of mercury once a week seem to give relief in some of these cases. Muriate of ammonia (20 grains three times a day) and benzoic acid (3 to 6 grains three times a day) are favourite remedies on the continent. In health, benzoic acid is excreted in the urine in the form of hippuric acid; but in jaundice Kühne has shown that benzoic acid and benzoates pass unchanged into the urine. I have given podophyllin (½ grain every other day) in several cases, but can offer no opinion as to the advantages of the remedy. In some cases inspissated bile appears to do good. Dr. Harley has had it prepared by Messrs. Savory and Moore, enclosed in gelatine capsules—a very useful suggestion, as the bile is not set free until it reaches the duodenum.

In cases of jaundice depending upon permanent closure of the duct, as from pressure of a tumour, impaction of a gall stone, &c., the jaundice continues, and bile passes off in the urine as long as the liver retains the power of secreting it. I shall not enter into the consideration of the treatment of those terrible cases in which the jaundice depends upon acute wasting of the liver, or upon the rapid disorganisation which sometimes follows a severe blow. The greatest caution should always be exercised in giving an opinion as to the cause of jaundice, and also as regards the prognosis. For further information upon the subject of jaundice, the reader is referred to the works of Dr. Budd "*On the Liver*," Dr. Harley "*On Jaundice*," and Dr. Thudichum "*On Gall Stones*."

CHAPTER XII.

Urine in Disease. Soluble Substances which do not exist in the Healthy Secretion—Sugar, Alcapton, Leucine, Tryosine, Inosite, Acetone, Cystine. *Sugar in Healthy Urine—Diabetes—General Characters of the Urine in Diabetes—Colour—Smell—Of the Urea and other Constituents—Albumen in Diabetic Urine—Specific Gravity—Reaction—Deposits—Diabetic Sugar, or Glucose*—Tests for Diabetic Sugar—*Moore's Test—Trommer's Test—Barreswil's and other Solutions—Circumstances interfering with the Action of Trommer's Test—On Testing for Sugar when only Traces are present—Brücke's Test for Traces of Sugar—Of the Yeast Test—Maumené's, or the Perchloride of Tin Test—Bismuth Test—Chromate of Potash Test*—Of Estimating the Quantity of Sugar—*Volumetrically—Fermentation—Dr. Garrod's Method—The Polarising Saccharimeter—Dr. Roberts' Plan*—Observations upon the Nature and Treatment of Diabetes—*Amyloid of Glucogenic Matter—Bernard's Researches—Views of Dr. Pavy and Dr. Harley—On the Formation of Amyloid, Fat, &c., in the Liver-cell—Dr. Mc Donnell's Observations—Of the Clinical Importance of Sugar in the Urine—Cataract in Diabetes—Origin of the Urea in Diabetes—Sugar in the Urine in Disease of the Respiratory Organs—The Experiments of Reynoso and Déchambre repeated—Analyses of Urine in Diabetes*—On the Treatment of Diabetes—*Substitutes for Bread—Diet—Wines—Pepsin—Medicine*—Alcapton, Leucine, Tyrosine, Inosite, Acetone, Cystine.

267. **Sugar in Healthy Urine.**—Traces of sugar are stated to be present in healthy urine, by Brücke, whose observations have been confirmed by Dr. Bence Jones. The proportion is, however, not sufficient to be recognised by the ordinary tests, unless some of the

other urinary constituents are first separated. It is possible that the colouring matter in healthy urine may be the source from which the small quantity of sugar present is derived. Schunk has shown that the substance from which indigo is obtained exists in the plant as a body he terms indican. This indican, when heated with strong acids, splits up into indigo blue, indigo red, and a kind of sugar ($C_{12}H_{10}O$). My friend Professor Bloxam has shown that specimens of urine which give no indications of the presence of sugar (copper test), when heated with sulphuric or hydrochloric acid, deposited a brown precipitate of the same composition as anthranilic acid ($C_{14}H_7NO_4$), a product of the decomposition of indigo blue. These deposits being separated by filtration, it was found that the clear fluid gave *decided indications of sugar.* (Bowman's "*Medical Chemistry,*" fourth edition, p. 15.)

Occasionally traces of this substance may be detected in the urine of persons who are not suffering from any particular symptoms. It may be excreted for days, or even for a few weeks at a time, in small proportion. These cases do not generally pass into confirmed diabetes, but they should be carefully watched by the practitioner. Sometimes, after abstinence from food for some hours, a meal, consisting entirely of starchy matter, will cause sugar to appear in the urine, and if a person, under these circumstances, take a quantity of cane sugar, a temporary diabetic condition will almost certainly be induced.

DIABETES.

268. Diabetes.—Although sugar may have been detected in the urine daily for several weeks, recovery often takes place. Diabetes may last for many years, but it frequently causes death in from one to four years. Although much light has been thrown upon the production of sugar in the animal body of late, no satisfactory explanation of these cases has yet been offered, nor do we know anything of the condition of the system which precedes and ushers in the fatal form of diabetes.

Two kinds of diabetes have been described—*diabetes mellitus* and *daibetes insipidus.* I have already had occasion to allude to the latter (§ 195), and have mentioned that in this condition large quantities of pale urine, containing little solid matter, and, it need scarcely be repeated, no sugar, are passed, it is therefore quite

unnecessary to describe this condition as a distinct disease; the term *diabetes* should never be applied to it. Diabetes is sometimes called *mellituria* or *glucosuria.*

269. General Characters of Diabetic Urine: Colour: Smell.—Diabetic urine usually possesses a peculiar smell, which has been compared to that of violets, apples, new hay, whey, horses' urine, musk, and sour milk. Such comparisons, serve only to show how difficult it is to give by description a correct idea of a particular odour. The *colour* of diabetic urine is generally pale. Sometimes, but not usually until after two or three days, the surface becomes covered with a whitish film, owing to the development of the *Sugar fungus* and *Penicilium glaucum.* It has a sweet taste, and often attracts a great number of flies. This is sometimes the first thing which directs the attention of the patient to his urine. Diabetic sugar sometimes disappears from the urine, and *Inosite,* a substance nearly allied to sugar, but obtained normally from muscles, takes its place.

270. Of the Urea and other Constituents.—The quantity of urea varies greatly in different cases of diabetes. In advanced cases it is diminished, but a considerable excess is often excreted. In one case reported by Prof. Sydney Ringer, that of a woman weighing 104 lbs., 764 grains of urea were excreted in 24 hours, which corresponds to 7 grains per pound of the body weight, the quantity in health being only 3·5 for each pound weight of the body. In one of Dr. Garrod's cases as much as 1085 grains of urea and 3,500 grains of sugar were eliminated in 24 hours.

The observation of Lehmann, that diabetic urine invariably contains *hippuric acid* and *never uric acid* is undoubtedly erroneous. In this country, at least, it is not uncommon to meet with an abundant deposit of uric acid. Dr. Prout regarded the presence of uric acid as a favourable sign. The cases in which I have observed it have not been very severe cases. In several I have seen an abundant deposit of uric acid. *Hippuric acid* is said to be present in diabetic urine (Lehmann and others); but in some specimens of urine, in which Dr. Garrod sought for it, he failed to detect it. (Gulstonian lectures, "*Brit. Med. Jour.*," 1857.) I have detected it.

Sulphocyanogen has been detected in diabetic urine by Schultze. Perchloride of iron strikes a red colour if sulphocyanides be present.

Heller states that the *uroxanthin* is increased, and Schunk obtained much indigo from diabetic urine. A reddish tint is often produced by the addition of nitric acid, but this is often observed in various specimens of urine which do not contain sugar.

271. Albumen is sometimes present in diabetic urine. Garrod detected it in ten per cent. of the cases. Dupuytren and Thènard considered it a favourable symptom. Rayer, on the other hand, considers it arises from renal disease. In a case which I saw lately, the only symptoms were dyspepsia and the secretion of rather a large quantity of urine (3 pints). Diabetes was not suspected. I examined the urine, and found an abundant precipitate of albumen, with a large quantity of sugar. I expressed a very unfavourable opinion as to the result, although emaciation had scarcely commenced. The patient died about six months after I had seen him. Albumen was detected during six months, and may have been present at an earlier period of the case. The first specimen of urine was of specific gravity 1028, and contained albumen and sugar. The former was not estimated.

Analysis 48.

Water	922·00
Solid matter	78·00
Urea	12·00
Sugar	38·00
Fixed salts	10·60

A specimen examined a month afterwards, the diet having been properly restricted, had a specific gravity of 1023, and was high coloured.

Analysis 49.

Water	936·80
Solid matter	63·20
Urea	8·16
Sugar	46·15
Albumen	2·21
Fixed Salts	1·40

Dr. Gibb found albumen in the urine in the pelvis of one kidney, and sugar in that present in the other in a case of death from cancer

of the liver. The urine containing albumen had a specific gravity of 1015, and that containing sugar a specific gravity of 1026.

Albumen should always be sought for in diabetic urine; and it should be borne in mind that its presence interferes with the reaction of the copper test (§ 277).

272. Specific Gravity—Reaction—Deposits. The specific gravity of diabetic urine is very high, almost always above 1030, and it sometimes reaches 1050. In some cases, however, the specific gravity does not differ from the healthy standard, and may be as low as 1010. This fact shows that we must not conclude that sugar is necessarily absent in urine of low specific gravity. Its reaction is generally acid, sometimes excessively so.

Deposits are not often met with in diabetic urine; those which have come most frequently under my own notice are deposits of the *phosphates*, and deposits of *uric acid*. The fixed salts are generally present in small quantity, and chloride of sodium is often altogether absent. The extractive matters are, as a general rule, relatively much diminished in quantity; but in some cases they exist in considerable proportion.

273. The Quantity of urine secreted by patients suffering from this malady is sometimes enormous, and in many cases this is the first point to attract attention to the disease. Some patients have passed as much as twenty pints of urine *per diem*, and P. Frank mentions a case in which the enormous quantity of fifty-two pounds was discharged in twenty-four hours. The proportion of solid matter passed in twenty-four hours varies greatly in different cases; it not unfrequently exceeds two pounds, the greater part of which is composed of sugar.

274. Diabetic Sugar is easily obtained from the urine when but little urea and extractive matter are present. That particular form of grape sugar or glucose which is obtained from diabeted urine differs both from the sugars of fruits, and also, in some particulars, from the sugar obtained from the liver. It generally appears as a treacle-like mass, but of a pale brown colour, which does not crystallize, especially if heat be employed in evaporating the solution. If, however, some of the urine of specific gravity 1050, from a bad case, be allowed to evaporate at a temperature of 100°, small warty

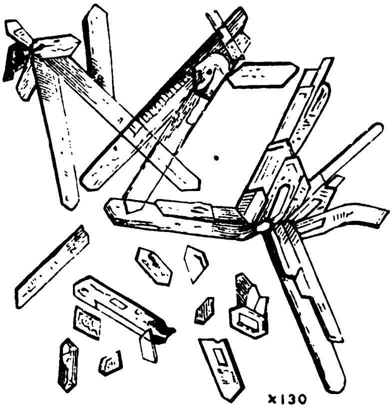
masses, of a rounded form, soon make their appearance. Under the microscope, these are seen to have projecting from the surface very beautiful crystalline plates. When a considerable quantity of the sugar has crystallized, it may be washed with ice-cold water, well pressed between folds of bibulous paper, and dried over sulphuric acid. It is now in many cases, nearly colourless, and, after two or three crystallizations, from distilled water, it becomes nearly pure. In Plate XIII., Fig. 66, some beautiful crystals of grape-sugar are represented. These were obtained by allowing a few drops of diabetic urine, containing a mere trace of urea and salts, to evaporate *spontaneously* on a glass slide. Similar crystals were obtained from the tears of the patient (case reported by Dr. Gibb, in "*Archives of Medicine*," Vol. I., p. 250). I have obtained crystals from several specimens of diabetic urine. These crystals are very beautiful objects when examined by polarised light. When burned they leave scarcely a trace of residue. It is curious that crystals of diabetic sugar have not been figured before.

275. Of the Torulæ developed in Diabetic Urine.—There are two kinds of fungi which are developed in diabetic urine—the yeast fungus, and the penicilium glaucum. The former is characteristic of saccharine urine, and Dr. Hassall considers the development of this fungus a most valuable test. ("*The Urine in Health and Disease,*" p. 146, Figs. 43, 44.) It is necessary, however, to set the urine aside for a few days, before the fungus will form, so that it is inapplicable as a test if we desire to determine within twenty-four hours if the suspected urine contains sugar. In many cases, no fungus whatever is to be found, even in two days. Moreover, the young sporules of the sugar fungus cannot be distinguished from those of penicilium glaucum. The microscopic characters of these fungi will be described under the head of Urinary Deposits (Chapter XV).

Tests for Diabetic Sugar.

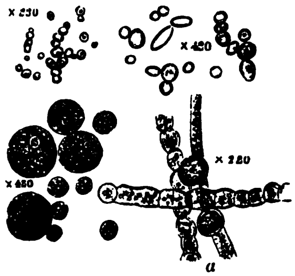
The presence of grape sugar in urine is readily ascertained by the application of certain tests, and if moderate care be taken in the examination, the detection of this substance is not open to many fallacies, unless mere traces are present, in which case see §§ 280, 281.

Fig. 66.



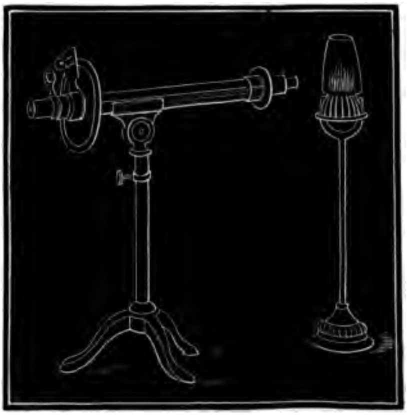
§ 274

Fig. 66*.



§§ 275, 350

Fig. 67.



§ 288

Fig. 68.

§ 287

To face page 222.

276. Moore's Test for grape sugar consists in adding, to the urine suspected to contain it, about half its bulk of liquor potassæ. If sugar be present, the mixture becomes of a rich brown colour upon boiling, which increases in intensity if the boiling be prolonged. The brown colour of the solution is owing to the formation of mellassic or sacchulmic acid; glucic acid is also produced in the decomposition. This test, however, cannot be depended upon for detecting the presence of small quantities of sugar, because there are some other substances besides sugar which will cause the development of the colour in a slight degree. If excess of nitric acid be added, a strong treacle-like odour results, and the solution becomes pale.

277. Trommer's Test.—Of all the tests which have yet been proposed, that originally suggested by Trommer, or some slight modification of it, will be found of the greatest practical value for showing the presence of sugar in diabetic urine, in clinical investigations. Trommer's test is applied as follows:—A small quantity of the urine is poured into a test tube, a drop or two of a solution of sulphate of copper is to be added, and about half as much liquor potassæ as there is of urine. If sugar be present in any quantity, the precipitate at first formed will be redissolved, and the solution will be of a *dark blue* colour. If only traces of sugar are suspected to be present, one drop of the sulphate of copper solution will be sufficient. The dark blue solution is now to be heated to the boiling point, and if sugar be present, a pale *reddish brown precipitate of suboxide of copper* is immediately thrown down. Instead of boiling the mixture, it may be allowed to stand for some time, when a similar deposit will gradually subside. If the suboxide is only reduced after prolonged boiling, *this cannot be taken as good evidence of the presence of sugar*, for under these circumstances there are some other substances which will cause the reduction of the oxide of copper. Again if the solution simply *change colour* by boiling, *without the occurrence of a distinct precipitate or the production of an opalescence*, we must not infer that the change is necessarily due to the presence of sugar, for almost all specimens of urine exhibit this change. A flocculent precipitate of earthy phosphate, which always takes place, cannot be mistaken for the suboxide, as it is quite colourless, or of a pale greenish tinge. The reaction alone

characteristic, is the production of a brown or yellowish precipitate (varying in quantity according to the amount of sugar the urine contains), either after the mixture has stood for some time, or upon boiling it not longer than for a minute.

If albumen be present, the reduction of the oxide of copper does not take place, so that in using the copper test we must ascertain that this substance is absent. Albumen may be removed by precipitation by heat and acid and subsequent filtration, the free acid being neutralised with potash or soda, but *not by ammonia*, before the application of the test; or the albumen may be separated by sulphate of soda (§ 282). Ammonia dissolves suboxide of copper. It has been shown that leucine, allantoin, creatine and creatinine, cellulose, tannin, and chloroform, have the power of producing a precipitate of suboxide of copper, like grape-sugar, and more recently, M. Berlin has proved that uric acid possesses to some extent the same property.

278. Modifications of Trommer's Test have been proposed by Barreswil, and others, the most applicable, however, according to Lehmann, being that of Fehling. (Lehmann's "*Physiological Chemistry*," by Day, Vol. I., p. 288. Cavendish Society.) The action of these test solutions is the same, and depends upon the following circumstances:—The protoxide of copper is not dissolved by an alkali alone; but, if certain organic matters be present, complete solution occurs. Tartaric acid and bitartrate of potash do not cause the reduction of the suboxide at the temperature of ebullition, and these are the salts usually employed. If grape sugar be present, however, the protoxide is reduced to the state of suboxide of copper when the mixture is boiled. The composition of Barreswil's solution, which was used by Bernard in his experiments, is given below. These tests are more easily applied than the sulphate of copper and potash. I shall, therefore, give the composition of some of the best solutions—Fehling's solution is made as follows:—69 grains of sulphate of copper are to be dissolved in 345 grains of distilled water; to this solution a concentrated solution of 268 grains of tartrate of potash, and then a solution composed of 80 grains of carbonate of soda in an ounce of distilled water are to be added; the mixture may be poured into a 1,000 grain measure, and filled up with water.

Barreswil's solution is composed of the following constituents:—

Cream of tartar	96 grains.
Crystallised carbonate of soda . . .	96 „
Sulphate of copper	32 „
Caustic potash	64 „
Water	2 fluid ounces.

Dr. Pavy recommends the following modification of Fehling's solution. Half a grain of sugar exactly reduces the oxide contained in 100 minims of the solution.

Sulphate of copper	320 grains.
Tartrate of potash (neutral) . . .	640 „
Caustic potash (*potassa fusa*) . . .	1,280 „
Distilled water	20 fluid ounces.

The tartrate of potash and caustic potash are to be dissolved together in one portion of the water, and the sulphate of copper alone in the other. The two solutions are then mixed. (" *On Diabetes.*")

In using these tests, it is only necessary to add about an equal bulk to the urine in a test tube, and then to boil the mixture. If sugar be present, the precipitate of suboxide occurs immediately. The application of this solution to the quantitative determination of sugar has been considered under *volumetric analysis* (§ 47).

Trommer's, or one of the above mentioned modifications, will be found the most delicate test which can be used, when only small quantities of sugar are suspected to be present, and the tartrate of copper solution is applied as easily as the liquor potassæ test, while the results obtained from it are far more to be depended upon. The tartrate solutions become decomposed by the action of the light, and some suboxide is deposited. In this case, its strength is of course impaired. It will also, after having been kept for some time, deposit suboxide, when boiled by itself; in which case a little fresh potash should be added.

279. Circumstances interfering with the action of Trommer's Test.—Some years since I endeavoured to ascertain the cause of certain anomalous results, which were occasionally met with in employing the test; and as these to some extent explain the discrepancies of different authorities with reference to the presence or absence

of sugar in the urine in certain cases, it is well to allude to them here. The following results were obtained:—

1. The precipitate of suboxide of copper was readily dissolved by acetic, hydrochloric and nitric acids. It was also dissolved by ammonia.

2. The precipitate was insoluble in a solution of chloride of sodium, but was readily dissolved by a weak solution of chloride of ammonium.

3. The addition of a few drops of chloride of ammonium previous to boiling entirely prevented the precipitation of the suboxide, the mixture retaining its greenish colour. Upon adding some solution of potash, however, the precipitate of suboxide was produced, and ammoniacal fumes were given off at the same time. If a moderate quantity of solution of chloride of ammonium was present, the precipitate did not occur upon the addition of potash, even after very prolonged boiling.

4. If a drop of a very dilute solution of the chloride of ammonium was added to a pretty strong solution of sugar, and, after the addition of the tartrate, the mixture was boiled, no precipitate took place, but the solution became of a pale brown tint; the suboxide being immediately thrown down upon the addition of a few drops of a solution of potash, with the development of ammoniacal fumes. In the above cases in which no precipitate took place, it was ascertained that there was the usual excess of alkali present in the test solution.

5. A solution of oxalate of ammonia also prevented the precipitation of the suboxide, but a greater quantity of this salt than of the chloride of ammonium was required.

6. A neutral solution of urate of ammonia (artificially prepared) also prevented the reduction of the suboxide, and dissolved the precipitate if added to it. On carrying out this experiment further, it was found that the *precipitate of suboxide of copper was dissolved by urine containing an excess of urate of ammonia.*

7. A solution of grape-sugar in water was prepared, and by a preliminary experiment it was ascertained that, upon being boiled with the tartrate test, an abundant precipitation of suboxide took place.

To a portion of the precipitate of suboxide produced in this way, about a drachm of healthy urine, immediately after it was passed, and while yet warm, was added, and the reddish precipitate was

instantly dissolved, forming a perfectly clear solution. Upon further boiling, a slight precipitate of phosphate took place. The suboxide, however, could not be precipitated by the further addition of potash and prolonged boiling.

8. Upon mixing a small quantity of grape-sugar with the same specimen of healthy urine, and boiling the mixture with the tartrate test, *no precipitate*, except a little phosphate, was produced. About half an ounce of the same mixture of urine and grape sugar was placed in a test tube, mixed with six drops of yeast, and inverted over mercury. The whole was then placed in a temperature from 70° to 100° for about twelve hours, at the end of which time the tube was found quite filled with gas, and all the liquid was expelled into the vessel in which it had been placed. The specimen of urine with which the above experiments were tried, was allowed to stand in a still place; and when it had become quite cold, an abundant precipitate of urate of ammonia was found to be present.

9. A portion of the aqueous solution of grape-sugar was mixed with a strong solution of urate of ammonia (artificially prepared), and then a certain quantity of the tartrate solution was added, and the mixture boiled. The characteristic precipitate, or opalescence, was not produced, but the mixture became of a pale fawn colour. In a weak solution of urate of ammonia, the characteristic precipitate appeared after boiling the mixture for some minutes.

So that, although much sugar is present, the colour of the mixture may be merely changed to brown, and no precipitate whatever may take place.

10. A solution of grape-sugar was treated with a drop of a dilute solution of chloride of ammonium, and boiled with the tartrate solution. The mixture became of a brown colour, but no precipitate occurred. Upon the addition of a few drops of solution of potash, the precipitate of suboxide was produced.

A solution of grape-sugar, treated with Trommer's test, according to the usual method, behaved in the same way, in the presence of chloride of ammonium, as when treated with the tartrate of copper solution; but in this case a greater quantity of the chloride was necessary, for when only traces were present, ammoniacal vapours were given off, and the precipitate of suboxide subsided, as before remarked.

From the results of the above experiments, the following conclu-

sions with reference to the practical application of Trommer's test, and Fehling and Barreswil's solutions, and other modifications of the copper test, may be drawn* :—

1. That if the urine contain chloride of ammonium (even in very small quantity), urate of ammonia, or other ammoniacal salts, the suboxide of copper would not be precipitated if only a small quantity of sugar were present.

2. That unless there be a considerable quantity of one of the above salts present (in which case the blue colour will remain), the mixture will change to a brownish hue upon boiling, but no opalescence or *precipitate* of suboxide of copper will occur. When only a moderate amount of sugar is present, I have been unable to obtain a precipitate, under these circumstances, by the addition of potash to the solution, and prolonged boiling. By observation 8, it appears that a specimen of urine exhibiting this reaction may contain a large quantity of sugar, as ascertained by the yeast test.

3. That in many cases in which the precipitation of the suboxide is prevented by the presence of ammoniacal salts, the addition of potash to the solution, and subsequent boiling, will cause the production of a precipitate with the evolution of ammoniacal fumes. Hence, care should always be taken that there is a considerable excess of free alkali present.

4. When only small quantities of sugar are present in the urine, and the precipitate of suboxide of copper is not decided, the fermentation test should be resorted to.

Upon treating different specimens of diabetic urine with Trommer's test, or its modifications, it has often been noticed that in one case the precipitate is produced as soon as the mixture reaches the boiling point, or even before; while, in other instances, it is necessary to keep it in active ebullition for some minutes, before any precipitate is produced. This circumstance receives explanation from the facts above detailed with reference to the presence of ammoniacal salts; and other anomalous results, which must have occurred to many in the habit of employing this test, become explained.

Specimens of urine in which sugar is suspected to be present, and no decided precipitate of suboxide (which must be carefully

* Professor Brücke has recently drawn attention to the action of ammonia in preventing the precipitation of the suboxide of copper, and other points connected with this subject. Probably he had not seen the results just given, which were obtained in 1852, and published in the "*Med.-Chir. Review*," Jan. 1853, Vol. XI., p. 113.

distinguished from phosphate *) occurs, should be carefully fermented with yeast (§ 283) before any conclusion is arrived at.

280. On Testing for Sugar when only Traces are Present.—In fluids which are suspected to contain only mere traces of sugar, it is necessary to separate some of the other constituents before applying the test. The plan recommended by M. Leconte is the following:—Excess of acetate of lead is added, and the precipitate separated by filtration. The solution is concentrated by evaporation, treated with ammonia, and again filtered. The copper test is then applied. The objections to applying the reduction test to solutions containing ammonia has been already discussed. It is better to employ carbonate of potash, or soda, instead of ammonia. The excess of lead salt may also be removed from the filtered solution by passing sulphuretted hydrogen. The precipitate of sulphuret of lead is removed by filtration, and the liquid, after evaporation to a small bulk, may be tested.

Another plan recommended by M. Leconte is to treat the urine with acetic acid, and evaporate it to about the fifth of its bulk; it is then treated with alcohol, and after filtration from the salts, &c., the alcoholic solution is evaporated and tested. This plan is free from the objection that ammonia may cause the destruction of the sugar where only traces are present.

281. Brücke's Test for Traces of Sugar.—Neutral acetate of lead is first added to the urine and afterwards basic acetate of lead. The precipitate is to be separated by filtration, and ammonia added to the solution. The precipitate, by ammonia, is decomposed by oxalic acid, or suspended in water and sulphuretted hydrogen passed through it. The filtered solution contains the sugar, which may be detected by any of the tests already mentioned. By this process, the seventh of a grain of sugar may be detected, when diluted with upwards of six ounces of water, and two-thirds of the total quantity of sugar present in a solution can be separated by this process.

282. Testing for Sugar when much Albumen or allied Compounds are Present.—If such a mixture containing sugar, be boiled with about an equal weight of sulphate of soda in crystals,

* The precipitate of suboxide may be distinguished from phosphate by its solubility in ammonia.

the whole of the albuminous matters are separated, while the sulphate does not in any way interfere with the application of the sugar tests. By this process, the presence of sugar may be detected in blood or in the solid organs of the body. Bernard recommends animal charcoal for separating albumen, uric acid, casein, and fatty matters, from solutions which are suspected to contain sugar. The latter substance filters through the animal charcoal unchanged.

283. The Yeast Test.—This is one of the most satisfactory tests for the presence of sugar, and if tried with proper care can hardly fail in its results. Two test tubes, of the same form, and of equal size, are to be taken. One is nearly filled with water, and into the other a corresponding quantity of the urine is to be poured. An equal amount of yeast is now to be added to the liquids in the tubes, and after pouring in just sufficient fluid to fill the tubes, the thumb is to be carefully placed over the opening, and the tube inverted in a small cup of mercury.

The plan which I have found most convenient is the following:—A little india-rubber pad, slightly larger than the upper extremity of the tube is to be cut out of a sheet of india-rubber. When the tubes have been filled up to the brim with a little water, the pad is allowed to float on the surface; next a little cup or beaker is inverted, and carefully placed over the end of the tube. The india-rubber being pressed against the open end, the fluid is prevented from escaping. The whole may be inverted, and a little mercury having been poured into the beaker, the india-rubber may be removed with forceps, without any escape of the fluid. The tubes may be supported in position by a wire stand. Both tubes are then to be exposed, for a few hours, to a temperature of from 80° to 90°, and the comparative size of the bubble of gas in the upper part of each may then be noted. If an appreciable quantity of sugar be present, the bubble of gas in the tube containing the urine will be many times larger than that in the tube which contains the yeast and water. In the latter tube the bubble of gas merely arises from the small quantities of air previously mixed with the yeast, becoming disengaged, and floating to the surface. Fermentation, when carefully performed, is positive evidence of the presence of sugar, although it does not indicate the kind of sugar present.

The *carbonic acid* can be detected in the fermented liquid by

potash. A fragment of potash is placed in the tube, and the end immediately closed with the thumb. If carbonic acid be present, it is soon absorbed by the potash, and upon the closed end being placed under the surface of water, and the thumb removed, a quantity of water will rise in the tube equal to the volume of the carbonic acid absorbed.

The *alcohol* may be separated from the fermented liquid by distillation. After a few drops have passed over, they may be tested for alcohol, with the bichromate of potash test, as follows. The solution suspected to contain the alcohol is poured into a test tube, and a little dilute sulphuric acid added. A drop of solution of bichromate of potash is added, and the mixture heated. If alcohol be present, the brownish colour changes to a bright emerald green.

284. **Maumenè's Test.**—A little woollen rag, as merino, is cut into strips, and soaked for four or five minutes in a solution of perchloride of tin (one part of the perchloride to two parts of water). The slips are then dried over the water bath. A drop of the urine suspected to contain sugar is allowed to fall on a small slip of the prepared merino, which is then dried, and exposed to the dull red heat of a spirit lamp. If a trace of sugar be present, a black spot is produced.

285. **Bismuth Test.**—Böttger has lately proposed a new test for sugar. This consists in adding first of all potash, then a small quantity of subnitrate of bismuth; lastly, the mixture is boiled. If sugar is present, the oxide is reduced to metallic bismuth, which is precipitated in the form of a black powder. It has been asserted that sulphuret of bismuth is formed, but this seems not to be the case. Brücke shows that this test is more delicate than Trommer's (or the modification of it by Fehling); and he finds that the black precipitate is produced to some extent in specimens of healthy urine. The bismuth test may be also applied thus. A solution of carbonate of soda (crystallised carbonate 1 part, water 3 parts) is prepared, and a certain quantity added to an equal amount of the urine. A little basic nitrate of bismuth is then added, and the mixture heated to the boiling point. If sugar be present, a black precipitate is produced.

286. **Chromate of Potash Test.**—If equal parts of neutral chro-

mate of potash and solution of potash be boiled with diabetic urine, a green colour, owing to the presence of oxide of chromium, is produced (Horsley). Luton's test is a modification of this. A solution of bichromate of potash is decomposed by excess of sulphuric acid, and, upon the urine being boiled with the mixture, a beautiful green colour is produced. This reaction is not affected by urea, albumen, or the urates.

On Estimating the Quantity of Sugar.

The quantity of sugar is easily determined, though not with absolute accuracy, by fermentation. The quantity of carbonic acid formed may be measured, weighed directly, or its weight may be determined by ascertaining the loss of weight the urine has sustained from fermentation.

287. On Estimating the Quantity of Sugar by Fermentation.—If the carbonic acid is to be measured, the mixture of yeast and urine must be placed in a graduated tube inverted over mercury. When the fermentation is complete, which is generally the case in from six to twelve hours, at a temperature of 100°, the volume of gas may be read off, and, after correction for temperature and pressure (Miller's "*Elements of Chemistry,*" Vol. I., pp. 48, 180), the amount of sugar calculated. One grain of sugar corresponds to nearly one cubic inch of carbonic acid.

The carbonic acid may be weighed by causing it to pass through a solution of liquor potassæ, specific gravity 1250, in an ordinary Liebig's potash tube. One grain of carbonic acid corresponds to about two grains of grape-sugar. The urine (about 500 grains) with the yeast may be placed in a small retort, to the end of which is adapted a chloride of calcium tube, or a tube containing pumice-stone moistened with sulphuric acid, for the purpose of drying the gas. To the extremity of the drying tube the potash apparatus is connected. This is weighed just before and immediately after the fermentation, which should be allowed to proceed at a temperature of from 80° to 100° for twelve hours. The increase of weight is due to dry carbonic acid. Or, lastly, about 200 grains of urine with a little yeast are placed in a flask, to the mouth of which a small drying tube is adapted, as shown in Plate XIII., fig. 68. The disengaged carbonic acid passes through the little tube containing chloride of

calcium or fragments of pumicestone moistened with strong sulphuric acid, and escapes, while the watery vapour, which would otherwise pass away with it, is retained. The apparatus is to be carefully weighed before and after the experiment, and the loss indicates carbonic acid.

The results afforded by fermentation are not so accurate as those obtained by the volumetric process of analysis, which are described in §§ 47, 48.

288. Determination of Sugar by the Polarising Saccharimeter.—Biot, many years ago, proposed a plan for estimating the proportion of sugar in fluids, depending upon the influence which the solution of sugar exerted upon a ray of polarised light made to pass through a thick stratum. Under these circumstances, a succession of colours is produced in the following order: *yellow*, *green*, *blue*, *violet*, *red*. If, in order to produce this series of changes, the hand must be turned towards the right, the solution is said to divert the plane of polarisation to the right, or to exhibit *right-handed polarisation;* but if to the left, *left-handed polarisation*. Cane-sugar and diabetic sugar have the first property; the sugar of fruits the second. The amount of rotation varies according to the quantity of sugar present. Two or three different forms of apparatus have been made. Mitscherlich's and Soleil's are well known. A modification of Mitscherlich's, made for me by Mr. Becker, of the firm of Elliott, Brothers, Strand, is represented in Plate XIII., Fig. 67. The urine or saccharine fluid is placed in the long tube. At the end near the lamp is a prism of Iceland spar, the *polariser;* and at the other extremity another prism, the *analyser*. The latter crystal is connected with a movable bar, which can be rotated with the hand, and the arc through which it is carried can be accurately measured on the graduated circle with the aid of a vernier. The instrument is placed with the posterior aperture about two inches from a homogenous light,* and the prisms adapted to zero, which is found by arranging the posterior prism so that, the tube being empty, when the arm stands at zero, the little spectrum is quite dark. It is then ready for use. The tube is filled with the solution carefully filtered;

* The best light is a very good Argand or Leslie's burner, with a piece of white porcelain, like a reflector, but having a dull surface, behind; or a piece of thin ground-glass, or semi-opaque white glass, may be placed in front of the lamp.

and if dark coloured, it is to be decolourised in the first instance by animal charcoal. Upon moving the arm towards the right, it will be found that, after it has passed through a certain number of degrees, the colour of the spectrum becomes blue, and gradually violet and red. Now, the exact degree at which the colour passes from the violet to the red is to be noted; and the number will vary according to the quantity of sugar. The value of each degree is ascertained by examining in the first instance a few solutions having known quantities of sugar dissolved. Supposing that 50 grains of sugar, dissolved in a certain quantity of water, require a rotation of 20°, 100 grains in the same quantity of fluid will require a rotation of 40° before the violet colour would appear. This method is very simple and accurate.

M. Clerget ("*Annales de Chimie*," III., xxvi., 175) used Soleil's instrument, which was also employed by Dr. Bence Jones for determining the quantity of sugar in wines and in diabetic urine. ("*Med. Times and Gazette*," Vol. XXV., 1852, p. 102.) The apparatus consists of a polariser and an analyser, made of Iceland spar. The light, which should be bright, white, and homogeneous, is placed behind the polariser. Between the polariser and analyser is placed the tube containing the saccharine solution, as in the other apparatus. Before reaching the saccharine solution, the rays of light pass through a circular plate of quartz, "composed of two half circles possessing equal and opposite rotatory power." The colour of the two plates will be the same before placing in the sugar, but afterwards the colour varies much; and by moving the compensator, composed of two wedges of quartz, which can be slipped over each other, the colour will be equalised. The amount of movement required, or the thickness of the quartz, varies according to the amount of sugar present; and thus the proportion may be determined.

The cheapest, and at the same time the most simple and efficient, polarising saccharimeter, for medical purposes, is that of Dubosq of Paris. It should, however, be graduated on both sides of zero. It may be obtained of Messrs. Elliott, of the Strand, and other Philosophical Instrument Makers.

289. Dr. Garrod's Plan of Estimating the Quantity of Sugar.—Dr. Garrod has lately devised an instrument for estimating

the quantity of sugar in urine, founded on the principle that the alteration of colour caused by boiling a mixture of diabetic sugar and carbonate of potash varies in intensity according to the quantity of sugar present. A standard solution is prepared for comparison, by boiling with the carbonate of potash, a solution containing half a grain of sugar to the fluid ounce. This is placed in a clear glass tube of about half an inch in diameter. The solution of carbonate of potash is prepared by dissolving four ounces of the carbonate in six ounces of water, and the solution filtered.

In the first place, Moore's test is applied; and if the colour produced after boiling for a few minutes be deeper than an amber red, it is necessary to dilute the urine before making the quantitative determination. The darker the colour produced, the more the urine is diluted. An equal bulk, twice or three times its bulk, of water is to be added, according to circumstances; the exact proportion added must, of course, be carefully noted.

Thirty minims, by measure, of the urine, diluted or not, as the case may be, are mixed with an equal quantity of the carbonate of potash solution, and poured into a small flask. The measure is to be washed out with about a drachm and a half of water, which is also to be mixed with the solution. Next, the whole is to be boiled over a spirit-lamp for five minutes. When cool, the mixture is transferred to a graduated tube of the same calibre as that which contains the standard solution, and diluted with water until its tint is exactly the same as that of the standard solution. By a simple calculation, the quantity of sugar is easily found. Suppose it has been necessary to make the urine by dilution, forty times its original bulk, in order to obtain the exact tint, it will contain forty half-grains of sugar per ounce, or twenty grains of sugar. From these data, the proportion passed in the twenty-four hours is easily calculated. The apparatus was made by Messrs. Coxeter.

290. Dr. Roberts' Mode of estimating the Quantity of Sugar.—Dr. Roberts estimates the quantity of sugar in urine by ascertaining the difference in density of the fluid before the destruction of the sugar by fermentation, and after this process is complete. Two portions of urine, of four ounces each, are placed in separate bottles of about 12 ounces capacity. To one is added a piece of German yeast, about the size of a walnut; the other is tightly corked. Both

are placed in a warm place for twenty-two hours, when fermentation will be complete. The bottles are then removed to a cooler part of the room, and when two hours have elapsed, the density of the fluid in each bottle is ascertained by the ordinary urinometer. Every degree of density lost by the fermented specimen indicates one grain of sugar in each fluid ounce of urine. ("*Edinburgh Medical Journal*," October, 1861.)

Observations upon the Nature of Diabetes.

It is not possible to discuss this question, without entering upon the consideration of the physiological changes which occur in the healthy liver, and I shall therefore venture to bring under the reader's notice several points, which are not only of physiological interest, but which really have a most important bearing upon medicine.

It is almost needless to say, that the sugar, found in the urine in diabetes, is not formed by the kidney, since it may be detected in many secretions, and that modern research has proved conclusively that the liver is intimately concerned in the production of a substance, which is very readily converted into sugar.

291. Amyloid or Glucogenic Matter.—In many animals, and in many different tissues of the same animal, a substance is found which is closely allied to starchy matters, and which very readily undergoes conversion into sugar. This amyloid matter is constantly found in the liver, and it is formed by the liver cells. It is probable that, in the adult mammalian animal, in perfect health, this amyloid matter is formed in quantity in the liver alone; but in certain morbid states it is found in many different tissues, in the muscles, in the coats of the arteries, veins, and capillaries, and in various glandular organs. Even in health there seems to be a certain quantity of amyloid material produced in certain parts of the nervous system, and in several of the fœtal tissues it is to be detected in considerable quantity. (Rouget.)

The amyloid or glucogenic matter very readily undergoes conversion into sugar. If injected into the blood, it becomes converted into sugar, which is carried off in the urine.

292. Bernard's Researches.—The demonstration, by Bernard,

of the presence of a large quantity of sugar in the liver of all animals, his discovery of the glucogenic material or amyloid matter, which becomes converted into sugar, and the proofs he has adduced that the formation of sugar in the liver is influenced by changes in the nervous system (for instance, by irritating the floor of the fourth ventricle, a temporary diabetic condition is induced), are, without doubt, the most important discoveries which have been made in physiology during the present century. Bernard considers that the glucogenic material or amyloid matter undergoes conversion into sugar, and that this sugar is at last oxidised and probably resolved under ordinary circumstances into carbonic acid. Under certain altered conditions, however, the whole of the sugar that is formed is not decomposed, but much accumulates in the blood, and is at length separated from the circulating fluid by the action of the kidneys; or, there may be a much more abundant formation of sugar than usual without any corresponding increase in the destructive processes, so that a large proportion circulates in the blood and is continually being carried off in the urine.

293. Dr. Pavy's Observations.—Dr. Pavy asserts that the conversion of the amyloid matter into sugar does not proceed during life in the healthy state, but that it takes place constantly in the liver after death, while in disease the change occurs during life. It has been stated by Bernard and others, that the blood of the portal vein often contains no sugar, while that of the hepatic vein contains a considerable quantity, but Dr. Pavy asserts on the other hand, that only the *merest trace* of sugar is to be detected in the blood of the right side of the heart during life, if proper precautions are used in obtaining the blood. He states that it is necessary that the animal should be perfectly tranquil at the time of the operation, as there is always much sugar if any struggling occurs. Again, if the liver of an animal, immediately after death, be injected with a strong solution of potash or citric acid (100 grs. to each ounce of water), sugar is not found. Or if small pieces of the liver, taken from an animal the instant it is killed, be quickly frozen, according to Dr. Pavy, the *post-mortem* formation of sugar is prevented, and sugar is not to be detected in the liver thus treated.

If woorari or strychnine be injected beneath the skin of an animal near the medulla oblongata, diabetes is induced, and Dr.

Pavy has shown that section of the medulla oblongata, artificial respiration being kept up, also causes it. The division of the sympathetic in the thorax, or even the branches ramifying on the carotid and vertebral arteries produces the same result. This observer, therefore, has been led to conclude that in the normal state, the medulla oblongata, through the branches of the sympathetic, exerts an influence upon the changes going on in the liver, and prevents in some way the conversion of amyloid matter into sugar.

294. Dr. Harley's Observations.—Dr. Harley, on the other hand, considers that the formation of sugar does proceed during life, and in several experiments he has shown that sugar exists in the liver, although the greatest expedition has been employed in removing portions the instant death has taken place. Dr. Sharpey also took part in these experiments, and concurs in the conclusion that the presence of sugar in the liver is a natural condition, and not the result of *post-mortem* change. In one experiment the portal blood, at the instant of death, contained no sugar, while there was distinct evidence of its presence in the hepatic blood, as Bernard has stated. ("*Proceedings of the Royal Society,*" Vol. X., 1860, p. 290.)

Dr. Thudichum has raised many objections to Dr. Pavy's method of analysis, and has proved that when air, potash, and sugar, are mixed together, the sugar is decomposed. This observer concludes that Dr. Pavy failed to discover sugar in the liver when he injected potash into the portal vein while the liver was yet warm, because the sugar had been destroyed; while if the liver was allowed to cool first, sugar would be detected, because the whole of what was present would not have been destroyed. ("*British Medical Journal,*" March 17th, 1860.)

I have myself many times been surprised at the very distinct reaction which is obtained by testing cat's liver the instant death has occurred; and until Dr. Pavy has succeeded in obtaining portions of the healthy liver of the cat and dog without a trace of sugar, I think his view, that the liver does not form sugar during life in the healthy state, cannot be accepted. The least that can be said is that more conclusive experiments are undoubtedly required, before we shall be justified in giving up Bernard's view.

295. Remarks by the Author.—It seems to me almost proved

that the changes which continue to take place in the liver for a short time after death, are of the very same nature as those which occurred in the organ before death. I have noticed that warm water may be caused to traverse the capillaries of the liver for several hours after death, and still indications of sugar exist in that which is received from the hepatic vein. Much more sugar can in this way be obtained than existed in the liver at the time of death. The blood is soon washed out, so that this can have nothing to do with the conversion of the amyloid into sugar. During life, under normal circumstances, one would only expect to find mere traces in the blood, as the sugar would be carried off as fast as it was formed, and probably itself decomposed as fast as it was carried off.

I cannot think that the life of the animal can make all the difference which is supposed in the action of the liver. Surely if a considerable quantity of sugar can be demonstrated to exist in the liver immediately after death we are not justified in considering this a mere post-mortem change. A piece of cat's liver, the instant death has taken place, exhibits the presence of sugar in precisely the same manner as a piece of the same liver removed during life. It is doubtful if the death of the great central organs of the nervous system produces that immediate change in many of the nutritive and secreting operations of the body, which the supposed necessity for this very quick removal of the liver seems to argue.

Nor is it an answer to this objection to say that as certain of the nerve cells cease to manifest any activity the instant death takes place, it is possible that the liver cells may as instantly cease to perform their functions. We know that there are some cells which may exhibit their actions for a long time after death, and which will retain their vitality, so that they can be removed from one organism to another. The liver cells are more likely to agree in character with the cells of glands and secreting surfaces generally than they are with those of the very highest tissue in nature, and therefore it is impossible to resist the inference, except in the case of positive demonstration to the contrary, that the same substances are formed by these cells a few seconds after death, as were produced by them a few seconds before death.

There is no reason for supposing that the liver cell, unlike many other cells connected with different secreting organs, dies the instant the death of the animal takes place. Just as we have ciliary action

and other changes continuing in individual cells for some time after the death of the animal in whose organism they were found, so also we may reasonably conclude that changes which have been going on during the life of the animal really continue to occur in the cells for a certain time after its death.

Moreover, it is most probable that the changes taking place in the amyloid matter of the liver cell are not *vital changes* at all, but due rather to chemical and physical actions only. The outer part of the formed material of a liver cell in the living body is no more alive than the outer part of the formed material of a soft epithelial or of a cuticular cell. That physical and chemical changes may go on at a different rate, according as the blood is flowing quickly, slowly, or not at all, is reasonable, but actual demonstration is required before a view which supposes the changes occurring a few seconds before death to be essentially different from those taking place a few seconds after death, can be accepted. The opinion that the conversion of amyloid into sugar is essentially a post-mortem or abnormal change, may be entertained, but no one has yet succeeded in demonstrating that this opinion is correct.

296. On the Formation of Amyloid, Fat, &c., in the Liver Cell.—The different substances taken as food are not simply reduced to a soluble state in the stomach and intestines, and then absorbed; nor are they alone rendered soluble, and altered in physical and chemical characters by the secretions of the different glandular organs which are mixed with them, but they are taken up by the living matter of the cells, and completely new substances at length result; so that the fat, amyloid, and sugar, which may be obtained from the liver, are not the same substances as were absorbed from the intestines, nor are they the substances absorbed somewhat modified, but it is probable that they are new bodies altogether, possessing certain definite characters. The general opinion now held by physiologists is, undoubtedly, that the substances absorbed at the intestinal surface simply undergo change. But how is the change effected? Most physiologists seem to consider that change is effected while the materials in solution are in the blood, or during their passage through narrow channels on their way towards the chyle or blood; and attempts have been made to show that minute channels exist through the epithelium of the intestine, which lead by the narrow

extremity of the cell into the connective tissue corpuscles of the villus. What are the agents that effect the change in the fluid passing through the cells? This converting power is generally ascribed to the nuclei; but there is no evidence that nuclei have any power of exerting an influence or change upon matter which is at a distance from them. Moreover, it has been shown that soluble matters pass into the very substance of the nucleus, and that, under certain circumstances, the absorbed matter goes to increase the matter of which the nucleus is composed; while the outer particles of the nucleus (germinal matter) are resolved into new constituents, the new matter taking the place of this which becomes changed. The nucleus may remain of the same size, although a vast amount of nutrient matter has been taken up, and a corresponding proportion of new substances has been formed.

This is the meaning of the vast quantity of nucleus (germinal) matter existing in connection with every absorbing surface and in every gland. The pabulum does not simply pass between these nuclei or cells, but it passes into their substance, and becomes living germinal matter. Its whole relations are changed, and it becomes endowed with powers like that of the living matter which existed before it. The older living particles, in dying, become resolved into new but inanimate substances. The elements form new combinations. These compounds result, not from any changing powers of the nucleus acting at a distance, but depend upon the relation which the elements were caused to assume just before the death of the living matter, and the external conditions which existed at the time the death of the particles occurred.

The fat, amyloid, and sugar, after disappearing from the intestines, become completely changed, and entirely lose all their characteristics. They served but as pabulum to certain cells, which lived upon them and grew. The living particles of these cells at length die, and among the substances formed may be other kinds of fatty, amyloid, and saccharine matters; but these are new bodies, not the altered starch, fat, and sugar that were absorbed.

When sugar is absorbed from the intestine the quantity of amyloid in the liver is increased; and this has been used by Dr. Pavy as another argument against the glycogenic theory. He says that: "Instead of the liver *allowing sugar to pass through* it, and also *producing sugar itself*, it transforms that which reaches it into amy-

loid substance." This fact of the increase of the amyloid is no argument against the conversion of this into sugar under normal circumstances, unless it can be shown that the amyloid afterwards gradually disappears *without* undergoing conversion into sugar.

It is quite true that the supporters of the glycogenic theory have failed to show in what form the sugar is ultimately eliminated or applied to further purposes in the economy; but there seems to be a greater difficulty in accounting for the subsequent changes in the amyloid matter if we suppose that, normally, it does not undergo conversion into sugar. The conclusion that the amyloid undergoes conversion into fat requires to be supported by stronger evidence than has yet been adduced, before it can be accepted.

It must be borne in mind that the cells, at the circumference of the lobules of the liver, are those which become first gorged with fat in fatty liver, and that these are the cells which are principally concerned in the formation of bile. In cases of amyloid liver, the cells near the *centre* of the lobules are those which become so enormously enlarged in consequence of the accumulation of this amyloid matter. Are we to infer that, normally, amyloid is formed principally in the central part of the lobule, and bile and fat are produced at the circumference; or that the amyloid formed in the central part gradually becomes resolved into bile and fat as the cells gradually pass from the centre towards the circumference of the lobule? This cannot be so, because, to render it possible, the cells must move in a direction, from the centre to the circumference of the lobule, much more rapidly than is actually the case.

Looking at the question from an anatomical point of view, many facts tend rather to the conclusion that the marginal cells are those mainly concerned in functional activity, and that those near the centre are being developed, and will gradually take the place of the former as they are removed. In the normal state the central cells are certainly not actively concerned in secretion (*see* my Papers on the Anatomy of the Liver). I incline to the view that, in health, the amyloid matter is formed in the same cells with the fat globules, and that the outer part of these cells is being resolved into two classes of substances—biliary matters which do not permeate the ducts, and certain substances which readily permeate animal membrane, and are reabsorbed with the fluid which is removed from the bile soon after it is formed, while it passes along the ducts. Further

provision for the removal of such soluble substances exists in the gall bladder where further inspissation takes place. Amyloid readily becomes converted into sugar, but no one has succeeded in causing it to split up into sugar and fatty or biliary matters; but it is quite possible that the matter of which the outer part of the liver cell consists, may split into the above two classes of substances—the one class permeating animal membrane, the other possessing but very slight permeating properties.

297. Dr. McDonnell's Observations.—Dr. McDonnell ("*Proceedings of the Royal Society*," Vol. xii. 1863, p. 476) concurs in the views expressed by Dr. Pavy as to the amyloid matter not being transformed into sugar, under normal circumstances, during life, and endeavours to ascertain what becomes of this amyloid substance formed, not only in the healthy liver, but in the fœtus in many other tissues, such as the skin, horny tissues, muscles, &c. During active digestion, Dr. McDonnell has found, that the blood which leaves the liver, contains a protein compound resembling caseine, in larger quantity than ordinary arterial or venous blood. This he thinks results from the union of the nitrogen of the fibrin and albumen, decomposed in the liver, with the amyloid material. He conceives that the hydro-carbonous substances resulting from the disintegration of fibrin and albumen in the liver are thrown out as bile, while the nitrogen of these compounds reunites with amyloid to form this new substance like casein, which passes away in the hepatic blood.

298. Of the Formed Material of the Liver-Cell and of the Changes occurring in it.—The amyloid matter is found in the cells when no saccharine or starchy materials are taken in the food, and this is a strong argument against the view which concludes that it results from some assumed and unexplained metabolic action of the nucleus or cell wall, upon starchy or saccharine matters brought to the liver in the portal blood. In fact, we can obtain, among other substances, from the liver-cell, amyloid matter, albuminous matter, and fatty matter. Each of these constituents may vary greatly in quantity in the cells, but it has not been shown that the fat or albuminous matter results from changes occurring in the amyloid substance, or that the albuminous matter is resolved into fatty and amyloid. The germinal matter of the liver-cell gives rise to certain

substances, of which the outer part of the cell or '*formed material*' is composed. (There is no limitary membrane, or 'cell wall,' to the liver cell.) Among these may be recognised, *albuminous matters*, *fatty matters*, *amyloid matters*, *colouring matters*, but these are themselves undergoing change. It appears that the principal substances resulting from the disintegration of this formed material, under normal conditions, are *biliary matters*, which are excreted, and other substances which again pass into the blood. Among these latter are an albuminous material closely allied to casein, and a substance which probably takes part in the production of heat. This, according to the theory of Bernard, is sugar, resulting from changes occurring in amyloid matter; while Dr. Pavy considers that the substance resulting from the amyloid is more nearly related to the fatty class.

There can be no doubt that the relative proportion of the different constituents, which can be recognised in the formed material of the liver-cell, differs greatly in different animals, and in the same animal under different circumstances and at different times. The proportion of these constituents is greatly influenced by the nature of the food. It is clear that the varying proportion of oxygen in the blood, transmitted to the liver, will influence the proportion of the several constituents, resulting from the disintegration of the formed material, in a remarkable degree. The diminished supply of oxygen may cause the accumulation of a large quantity of fat in the liver-cells, while a large supply would have resulted in the secretion of an increased quantity of bile. This subject requires most extended research, but it seems to me that observations should be made from this point of view:—that the substances formed in the liver, some of which pass to the intestines in the form of bile, while others pursue an opposite direction and are carried in the blood to the lungs, result from the disintegration of the material, of which the outer part of the so-called liver-cell is composed, and are not due to any action exerted by the nucleus upon matters passing by or into, or simply coming into contact with, the cell, nor to any peculiar powers exerted by the supposed cell wall.

As to the ultimate changes of the sugar, supposing it to be produced normally, or of the amyloid, or the fat supposed to result from it, nothing positive is known. Bernard, without attempting to explain the successive changes, concludes that the sugar is at length

destroyed and excreted in the form of carbonic acid; and even Dr. Pavy, in his earlier experiments, showed that blood which exhibited strong indications of a quantity of sugar, was found to contain only traces after it had been caused to traverse the capillaries of the lungs. It is true that a solution of pure sugar is not decomposed by the direct action of oxygen, but this is no argument against the view that sugar in the venous blood is ultimately resolved into carbonic acid; for it is quite obvious that oxidation, as carried on in the body, occurs under conditions very different from those we are able to bring about in our laboratories. In fact Dr. Pavy himself showed that the destruction of sugar by respiration occurs only in blood which contains fibrin.

No one has any doubt that, in the majority of diseases known to us, this very process of oxidation is at fault. There may be quite oxygen enough in the fluids of the body, but the state in which it exists may be different, the conditions favouring its combination may be absent, or the substances may not be presented to its action in the normal manner, and so they are not decomposed. There are probably many compounds between the sugar which passes from the liver and the carbonic acid which is evolved from the lungs. This sugar may, under normal conditions, be taken up by the masses of germinal matter (cells, nuclei) existing in such great number in relation with the capillaries of the lungs, and the particles of which these cells consist, may become resolved into carbonic acid, among other substances, or the sugar may be taken up by the blood corpuscles, and the matter of which these bodies are composed resolved into carbonic acid and other matters. I merely offer these speculations for the purpose of showing that there yet remains much to be decided before we shall know precisely how fat, sugar, amyloid, and many other substances, become oxidised in the living organism.

With regard to this most difficult and highly interesting question, it seems to me that, in the present state of knowledge, the greatest caution ought to be exercised in forming a general conclusion. But I cannot help stating that, as far as I am able to judge, the evidence is at present strongly in favour of Bernard's view, that, in health, sugar is produced in the liver, and destroyed whilst it is in the blood. In the normal state the destruction of the sugar occurs at the same rate as its formation; while in certain lesions of the nervous system, and under other circumstances, more sugar is formed than

can be destroyed—or the quantity formed remaining the same, the normal conditions under which its decomposition takes place being absent or modified, it accumulates in the blood, and is excreted by the kidneys and other secreting organs, thus producing diabetes. Whether the excretion of a large quantity of sugar in the urine depends upon increased activity of the sugar-forming process, or results from the cessation of the destructive changes which occur normally, has not been determined. There can be no doubt that certain parts of the nervous system are seriously implicated in all cases, but whether the nerves exert a direct influence upon the sugar-forming or sugar-destroying processes, or only affect these operations indirectly through the control they exert upon the calibre of the arteries, and therefore upon the quantity of arterial blood distributed to the capillaries, is not known; but there are, I think, many facts which favour the latter view, while it has never been shown that nerves exert any *direct* influence upon the growth or action of any cells. They influence the processes of growth, formation, and secretion, by regulating the supply of nutrient material; and the process of disintegration is affected by the quantity of the soluble constituents of blood, rich in oxygen, that is permitted to bathe by the cells.

299. Of the Clinical Importance of Sugar in the Urine.— The existence of sugar as a normal constituent of urine has been already referred to (§ 267), but it is not uncommon to meet with specimens of urine from persons apparently in the enjoyment of good health, which exhibit unmistakeable evidence of the presence of sugar, there being sufficient to estimate quantitatively, without resorting to the processes referred to in §§ 280, 281, which are necessary to obtain evidence of the traces said to exist in specimens of healthy urine. I have often found from one to two grains of sugar in 1000 of urine, in cases where all traces of the presence of this substance have disappeared in a few days, without any of the usual restrictions as to diet; and I have noticed the presence of small quantities of sugar in the urine more frequent during the summer than during the winter months. I know other practitioners have made the same observation, and sometimes there exists much difference of opinion as to whether a patient has, or has not, diabetes. A short time since, I found very positive indications in the urine of a gentleman, who I

found, upon inquiry, had been in the habit of eating a large quantity of sugar with fruit tarts. Brown bread, restriction of sugar within moderate limits, and salines, soon caused the sugar to disappear from the urine. But in cases of fatty liver, and in that common condition in persons who live too well, where the liver is somewhat wasted as well as fatty, it is very common to find sugar in the urine. The diabetic condition, in these cases, may persist for weeks or months and then pass off entirely.

The highly important and interesting observations lately made by M. Hohl, in a case of diabetes where inosite (§ 321) was passed in large quantities, and seemed to take the place of the urea and sugar, must not be passed over.

The quantity of sugar is always much influenced by the quantity and nature of the food. It increases shortly after a meal, and it is undoubtedly augmented when much starch is taken. A meat diet, with bran or gluten bread, always causes a diminution of the sugar. Total abstinence from food, and rest, diminish the proportion; and it is increased by exercise, and by a large quantity of food. As much as two pounds of sugar may be excreted daily; but about one pound is the more usual quantity. I have now (1858) under my care, a girl, aged 19, who excretes daily about one pound and a half of sugar.

The dry harsh skin, the intense hunger and thirst, the emaciation, the tendency to the formation of tubercle in the lungs and other organs, are familiar to all who are acquainted with the clinical history of this disease. Dr. Garrod observes, that œdema of the legs is always present in diabetes. Although in some cases it is very slight, he states that it is always to be detected. I have failed to observe it in one instance.

Sugar has been found in the urine in cases of cholera, by Dr. Hassall and also by Heintz, but the former observer suggests that, as Heller has shown in this disease that the uroxanthin is in abnormal quantity, it is very probable that the sugar may be derived from this substance from decomposition. The same change may account for the presence of traces of sugar in many cases. (*See* § 267.) A diabetic state may be temporarily induced in animals, by certain lesions of the nervous system, but the condition soon passes off. Diabetes is a disease which does not occur in animals. Dr. Prout regarded diabetes as a form of dyspepsia, characterised by difficulty in assimilating the saccharine alimentary principle.

There can be little doubt that the liver is the gland which is essentially involved, although hitherto the nature of the lesion has not been discovered; indeed, no alteration, constant in all cases of the disease, has been made out by anatomical investigation. Diabetes is one of those diseases which often runs in families, and it is hereditary. The diabetic state is often temporary. It has been caused by injuries to the head. Dr. Gull and Dr. Barlow refer to cases in which it followed an attack of hemiplegia.

I have, myself, found sugar in the urine in pneumonia and phthisis, and have frequently met with it in cases of gradual contraction of the liver, accompanied with a corresponding condition of the kidneys, with albuminous urine. In one case the sugar and albumen seemed to alternate. Sugar would be present for a few days, while no albumen could be detected, and then albumen would appear and the sugar would cease for a time. Diabetes is generally accompanied with emaciation, but I have seen cases in which the patient was not only well nourished but corpulent. Not long since, I was consulted by a very robust and healthy-looking man, a farmer, weighing 13 stone, 6 lbs., who appeared to be suffering from dyspepsia. It was, however, found, upon examination, that the urine was of specific gravity 1028, contained a considerable quantity of sugar (38 grains in 1,000), and was loaded with albumen. There were no casts of the uriniferous tubes or other indications of renal disease. This case gradually became worse, although the proportion of sugar in the urine became reduced when he was put upon a properly regulated diet.

In cases of carbuncle, sugar sometimes appears in the urine, and towards the close of chronic exhausting diseases it has been detected.

300. Cataract in Diabetes.—It is well known that cataract is very frequently observed in diabetes, and sometimes at an early stage of the disease. Mr. Bowman has often diagnosed diabetes from the presence of cataract. Dr. G. Weir Mitchell and Dr. Richardson have shown that cataract could be caused in the frog, by injecting syrup under the skin, and they arrived at the conclusion that the opacity of the lens depended only upon the increase in the density of the fluids which bathed and permeated it. But it is probable that cataract, as it occurs in diabetic patients, is not due solely to this cause, seeing that it is not present in some of the worst cases of

diabetes, and exists in some slight cases in which the urine never reaches a high specific gravity. The cataract, too, will continue, although the diabetic state becomes much improved or passes off entirely.

In diabetes, wounds do not heal satisfactorily, and the surgeon should, if possible, avoid performing even a slight operation in cases of this disease.

301. Origin of the large Quantity of Urea in Diabetes.—There can be no doubt whatever that, in many cases of diabetes, the sugar excreted in the urine is not derived solely from the starchy matters taken in the food; for although the patient may be restricted to a diet consisting entirely of proteine and fatty substances, sugar is found in the urine.

The recent observations of the Rev. S. Haughton have confirmed this conclusion. He shows, in some cases which he investigated with the greatest care, that the sugar excreted had a double origin, having been in part derived from the starch in the food, and partly from the decomposition of proteine substance. He considers that the proteine compounds resolve themselves into glucose and urea without giving out work, the total work done in the body in diabetes being at a minimum. The large excretion of urea depends not upon *the work done in the body*, as in health, but results merely from decomposition. In this way the large excretion of urea is explained; and this cannot be accounted for upon the usual theory, that the urea is derived solely from the disintegration of tissue. ("*On the Phenomena of Diabetes Mellitus.*" Dublin, 1861.)

302. Sugar in the Urine in Disease of the Respiratory Organs.—Sugar has been detected in cases of disease of the respiratory organs, as pneumonia and bronchitis. In extreme cases of phthisis, sugar is occasionally detected in the urine, and towards the close of many exhausting diseases, a meal of starch is followed by the excretion of saccharine urine. I have shown the presence of a considerable quantity of sugar in the sputum in a case of acute pneumonia, just before the patient's death. It has been asserted by some observers, that sugar can always be detected in the urine after anæsthesia produced by chloroform, and in cases of bronchitis and emphysema. I have carefully tested for sugar in the urine of several patients who had taken chloroform, but did not succeed in detecting

it in a single instance. The presence of sugar is accounted for under these circumstances, on the supposition that in disease of the pulmonary organs the sugar is not further oxidised, and carried off as carbonic acid. But Bernard has shown that this theory has no foundation, and has proved that the condition of temporary diabetes produced by irritation of the floor of the fourth ventricle, close to the origin of the pneumogastric nerves, is not due to the impaired action of the respiratory organs, as Reynoso and others have supposed.

Bernard has brought forward various facts which militate against the above view; as, for instance, no sugar appears in the urine after complete section of the pneumogastric nerves, and in many other conditions where the respiratory function is impaired. Nevertheless, Reynoso ("*Comptes Rendus*," t. XXXIII., XXXIV.) states that sugar is present in the urine of persons who have been placed under the influence of chloroform, bichloride and iodide of mercury, salts of antimony, opium and narcotics generally, quinine, and carbonate of iron. He also states that, in pleurisy, asthma, and chronic bronchitis, hysteria, and epilepsy, he discovered sugar in the urine. The test employed, it is very important to observe, was Barreswil's solution; but before applying it, the extractive matters were removed. About 1,500 grains of the urine to be tested were treated with a solution of subacetate of lead. The precipitate was collected on a filter, and the excess of lead salt in the filtrate was decomposed by chloride of sodium; and the solution was again filtered. The clear fluid, after being concentrated, was treated with the copper solution. To another portion the yeast test was applied.

Michèa, who, it should be observed, employed Moore's test, failed to confirm the above conclusions. Déchambre ("*Gazette Medicale*," 1852) found sugar in specimens of urine obtained from several old people. The test employed was the same as Reynoso used, except that the excess of acetate of lead was decomposed with carbonate of soda instead of chloride of sodium. Dr. Bence Jones obtained "slight, but distinct" evidence of the presence of sugar in the urine of a patient who had been twenty-four hours under the influence of chloroform. The urine was examined according to Reynoso's directions. M. Blot also confirms Reynoso's observations to a great extent. He found sugar in the urine of pregnant women, and in those who are suckling children as soon as the milk was secreted.

It is possible that affections of the respiratory organs may be instrumental in producing the diabetic condition; but this may be due to the excitation of the peripheral extremities of the pneumogastrics, depending upon the altered state of the pulmonary membrane, being propagated along the trunks of nerves to that particular part of the medulla oblongata the artificial irritation of which in animals is known to induce diabetes. There are many facts which support the doctrine that the processes concerned in the production of the sugar are capable of being excited in a reflex manner, and they may therefore be included in the excito-secretory actions.

These observations of Reynoso and others seemed to be so important, that it was very desirable to repeat them. I therefore tried numerous experiments, but was unable to confirm the results. I often found the fluid change to a brown colour when heated with the copper solution; but, as I have shown, this is not a proof of the presence of sugar. I never conclude that sugar is present in a specimen of urine, unless a decided precipitate of the suboxide of copper is produced. Though this *precipitate* be very slight, it is characteristic. If it only amount to an opalescence, as I have before stated, it is sufficient; but a change of colour even to a dark brown, the solution still remaining clear, does not, I believe, indicate the presence of sugar.

These unsatisfactory results led me to institute the experiments upon the action of Barreswil's and Fehling's solutions, and different forms of the copper-test, which have been already described.

303. The Experiments of Reynoso and Déchambre repeated, with Negative Results.—The urine was tested as in Reynoso's experiments, except that carbonate of soda was used to precipitate the excess of subacetate of lead, instead of chloride of sodium. The specimens of urine passed by six patients under the influence of chloroform, for periods of time varying from ten minutes to half an hour, that of an old lady aged 87, of an old man aged 96, and of two children suffering from epilepsy, were carefully examined. In most, the solution became brown upon being boiled; but no opalescence or precipitate was produced. The urine of a healthy man, aged 24, was also subjected to examination, and became brown upon being boiled with the copper test. The results of numerous other experiments upon specimens of urine known to contain no sugar led me to

the conclusion that, in all the above cases, the urine was perfectly free from this substance. Kletzinsky has repeated Reynoso's experiments, and has failed to confirm his conclusions. Dr. Moore of Dublin (Heller's "*Pathological Chemistry of the Urine*," translated by W. D. Moore, A.B., M.B.T.C.D.) has examined the urine of twelve men and women whose ages varied from sixty to eighty-three, but was unable to detect sugar. We may, therefore, conclude that there is at present not sufficient evidence to prove that sugar is *habitually* excreted in the urine of old people, or by patients suffering from chest-disease, or by those under the influence of chloroform, etc. It is probable that it may be occasionally met with in some of the above cases.

304. Analyses of Diabetic Urine.—It is difficult to estimate the urea in diabetic urine by the old process; but the proportion may be ascertained by the volumetric method, which has been described (§ 48). The following analyses show the composition of the urine in some cases of diabetes.

Analysis 50.—Urine from a girl aged 19. Specific gravity, 1037; acid, clear, pale.

Analysis 51.—From the same. Specific gravity, 1036; acid.

Analysis 52.—From a man aged 30, about one month before death. Specific gravity, 1023.

Analysis 53.—From a woman aged 28, a week before death. Acid; specific gravity, 1027.

Analysis 54.—From a patient who was passing sixty ounces of urine daily. Reaction acid; specific gravity, 1021.

Analyses.

	50		51		52	
Water	916·50		894·90		946·8	
Solid matters	83·50	100	105·10	100	53·2	100
Urea Extractives			82·29	78·2		
Uric acid						
Alkaline salts Earthy salts	10·66	12·96	3·82	3·63	5·44	10·22
Sugar	not estimated.		18·99	18·08	20·24	38·04

	53		54	
Water	934·2		946·00	
Solid matter	65·8	100	54·00	100
Urea } Extractive matters }	16·94	25·74	21·54	39·18
Uric acid	1·64	2·49		
Alkaline salts } Earthy salts }	5·82	8·84	3·76	6·96
Sugar	41·40	62·91	28·50	52·7

Analyses 55, 56, 57 represent the composition of the urine in a case of diabetes now under my care in the hospital. The patient was a healthy-looking girl, only eighteen years of age. She had been suffering from the disease for about three months. Various plans of treatment were tried, without any marked results. She remained under treatment for six weeks, and then left the hospital. She drank from four to six pints of fluid daily; and, when living on a moderate meat diet, with a small quantity of bread, passed rather under a gallon of urine. The urine was analysed from day to day; and I select three specimens for illustration. When the last was obtained, her diet was restricted to bran-biscuits and milk. The results are expressed in grains, and represent the quantities passed in twenty-four hours. [*See Table, next page.*]

The Treatment of Diabetes.

305. Of the Treatment of Diabetes.—In the treatment of a case of diabetes, careful regulation of the diet is of the first importance. That starchy and saccharine substances taken in the food, cause an increased quantity of sugar in the urine, is proved beyond question, while, on the other hand, every practitioner is familiar with the improvement that invariably takes place in the condition of the diabetic patient, even a very short time after these and allied substances have been diminished in proportion, or withheld.

There are many cases of slight diabetes which recover directly starchy and saccharine matters are avoided, or even reduced in quantity. In such cases it would seem that the sugar in the urine is derived from those substances, while in very severe cases the excretion of sugar continues, although the patient lives upon a diet

Analyses.

	55		56		57	
	March 20th.	In 100 of solid matter.	April 2nd.	In 100 of solid matter.	April 23rd.	In 100 of solid matter.
Quantity of fluid drank in 24 hours	64708·75		36968·75		36968·75	
Specific gravity of Urine . .	1037		1043		1043	
Reaction	Acid.		Acid.		Acid.	
Water	78653·75		69364·50		50857·625	
Solid matter	8846·25		8510·50		6017·375	
Urea			512·30	5·430	455·000	7·561
Sugar	8750·00	98·910	7549·12	88·703	4889·326	81·253
Organic matter . .			141·07	2·447	501·287	8·333
Fixed salts . . .			308·11	3·620	171·762	2·853

consisting of albuminous matters and bran only. Patients suffering from the first form of the malady live for many years, and if proper precautions are taken, the disease may long be kept in abeyance, if it cannot be completely cured. In many cases the diabetic condition lasts for a certain time, passes off, and after an interval reappears. The disease may continue for many years, or it may carry off the patient in a few months. It is rare for a confirmed case to recover completely.

Except in very severe cases, it is neither expedient nor necessary to insist too strongly upon a very strict diet immediately the patient comes under treatment, for many rebel if this is attempted at once, who might be induced to submit to a fully restricted diet, if the system was introduced gradually. The quantity of wheaten bread may, at first, be reduced, and the proportion of meat may be increased, and brown may be substituted for white bread. Then some of the bran food may be tried, and gradually made to take the place of bread, and by employing a little ingenuity in using bran, eggs, cream, and glycerine, a perfectly restricted diet may be enforced without distress to the patient. The diabetic may be allowed to take his tea and coffee with cream instead of milk; we may allow jellies of various kinds, but of course they should not be sweetened with sugar. But we are no longer compelled to deny even sweet flavours to the diabetic, for he may use glycerine; the preparation now made so largely by Messrs. Price (Price's glycerine) is so pure, and its taste is so perfectly sweet, that it can hardly be distinguished from sugar.

Glycerine may be used for sweetening tea, coffee, and cocoa, it may be introduced in custards, and with eggs and gluten bread well softened, a very palatable kind of pudding may be prepared; glycerine, eggs, and bran may also be made into a light sort of cake or pudding, which may serve to vary the monotony of a strict diet.

The diabetic patient may be allowed a moderate quantity of milk, but it should be borne in mind that milk contains a form of sugar, and, therefore, is not to form a staple article of food in this disease. Various kinds of meat and fish may be taken. Fat and butter do no harm. Eggs may be taken if they agree with the patient, but sometimes they upset the stomach. Soups of various kinds—but not containing flour—cheese, cream cheese, cream, ham and bacon, may be eaten by diabetic patients.

306. Substitutes for Bread.—Some of the best subtitutes for wheaten bread are *Bourchardat's gluten bread*, or *M. Durand's Toulouse gluten bread*, *Callard's English gluten*, but the *bran biscuits*, prepared as Dr. Camplin directs, are far superior to either of these. The first contains about 25, and the Toulouse bread 26 per cent. of starch, while the last contains only traces of this material when properly prepared.

307. Formula for making Bran Cakes.—Dr. Camplin, who has himself suffered from diabetes, has proposed a most valuable kind of food made from bran. The bran is ground fine in a mill, sifted, and can then be made into a kind of cake. The directions Dr. Camplin gives are as follows—"Take a sufficient quantity (say a quart) of wheat bran, boil it in two successive waters for a quarter of an hour, each time straining it through a sieve, then wash it well with cold water (on the sieve) until the water runs off perfectly clear; squeeze the bran in a cloth as dry as you can, then spread it thinly on a dish, and place it in a slow oven; if put in at night let it remain until the morning, when, if perfectly dry and crisp, it will be fit for grinding. The bran thus prepared must be ground in a fine mill, and sifted through a wire sieve of such fineness as to require the use of a brush to pass it through; that which remains in the sieve must be ground again until it becomes quite soft and fine.* Take of this bran powder 3 ounces (some patients use 4 ounces, the other ingredients as follows), three new-laid eggs, 1½ ounce (or 2 ounces, if desired,) of butter, about half-a-pint of milk; mix the eggs with a little of the milk, and warm the butter with the other portion; then stir the whole well together, adding a little nutmeg and ginger, or any other agreeable spice. Bake in small tins (pattipans), which must be well buttered, in a rather quick oven for about half-an-hour. The cakes, when baked, should be a little thicker than a captain's biscuit; they may be eaten with meat or cheese, for breakfast, dinner, and supper; at tea they require rather a free allowance of butter, or may be eaten with *curd* or any of the soft cheeses. It is important that the above directions as to washing and drying should be exactly followed, in order that it may be freed from starch, and rendered more friable." ("*On Diabetes*," page 86.) The mill may be obtained from Mr. Gollop, 149, Cheapside.

* This is particularly necessary in cases of irritable bowels.

The bran powder and biscuits cost 1*s.* 6*d.* per pound. The gluten biscuits cost 2*s.* 6*d.* a pound.

308. Almond Cake.—Dr. Pavy ("*On Diabetes,*" p. 154) has recently added another substitute for wheaten bread—Almond cake and bread. A very palatable kind of biscuit has been prepared with egg and blanched almond powder, according to Dr. Pavy's suggestions, by Mr. Hill, of Bishopsgate Street. Upon this diet, the quantity of sugar in the urine, in the case of two of Dr. Pavy's patients, became reduced to less than 700 grammes per diem, while on a mixed diet it had amounted to from 6,000 to 9,000 grammes, and the urine diminished in quantity from 150 and 200 ounces to about 60 ounces in the twenty-four hours.

309. New Glycerine Sponge Cake.—It occurred to me, some time since, that the bran, with eggs and glycerine, might be made into a form of sponge cake, and I tried some experiments with this view. Mr. Blatchley has lately succeeded in making for me a most excellent diabetic food of these ingredients. It is not only palatable, but really nice. When freshly made, the cakes are as soft as ordinary sponge cake. They may be dried, and will keep for any length of time. In the dry state they can be readily softened in soup, tea, or coffee. They can be flavoured with lemon, or other flavour, according to taste. A similar kind of food can be made with savory gravy; and in cases where the digestive powers of the stomach are impaired, a few grains of pepsine can be added with advantage. Food made on a similar principle with ordinary flour, concentrated extract of meat, and pepsine, is valuable in many cases when the stomach is very weak and irritable.

The sponge cakes are prepared by Mr. Blatchley, 362, Oxford Street. When fresh they cost 2*s.* 6*d.*, and when dry 3*s.* 6*d.*, per pound. They form by far the most palatable diabetic food I have ever tried.

310. Manufacturers of Gluten Bread, &c., for Diabetic Patients.—The various substances required for diabetic patients may be obtained of the following firms, which are arranged alphabetically:—

Van Abbott, G., and Co., Howford Buildings, 148½, Fenchurch

Street, and 5, Princes Street, Cavendish Square—Gluten Bread—Toulouse Gluten Bread, &c.

Bewley & Evans, 3 & 4, Lower Sackville Street, Dublin—Gluten Bread, &c.

Bell, 338, Oxford Street—Gluten Bread, &c.

Blatchley, E., 362, Oxford Street—Bran and Gluten—Bran and Gluten Cake and Biscuits—The Glycerine Sponge Cake.

Bullock & Reynolds, 3, Hanover Street, W.

Hill, W., 60 & 61, Bishopsgate Street, E.C.—Almond Cakes, Biscuits, and Rusks.

Gollop, 149, Cheapside—Maker of Mills for Grinding Bran.

Smith, Baker, Gower Street, N.—Bran Biscuits, &c.

311. Wines.—Of wines containing little sugar, amontillado, mansanilla, and manilla, may be taken, and good claret may be recommended. Whisky or brandy are also admissible. Vichy, or other alkaline water may be taken in moderate quantity, but it is well to restrain the diabetic patient from taking too much fluid. Lime water has been recommended as well as potash and soda waters.

312. Vegetables.—The best vegetables are cabbage, French beans, lettuce, and watercresses. Asparagus should not be taken, as, according to Dr. Harley, when eaten in quantity, temporary diabetes may be induced. Potatoes and all vegetables containing much starch, and fruits, both fresh and dried, as they contain sugar, must not be eaten.

313. Medicines.—Various medicines have been prescribed in cases of diabetes, and there can be no doubt that benefit often results from the use of ordinary tonics, and the mineral acids are sometimes of service. Phosphoric acid allays the thirst. A very agreeable drink may be made as follows:—acid phosph. dil. two drachms, glycerine, half-an-ounce, water half-a-pint; mix: a few tablespoonfuls of this may be taken occasionally during the day. Various bitter infusions, and citrate of potash and ammonia, sometimes appear to do good. Opium is with some a very favourite remedy, but in the cases in which it has been given the diet has been altered as well, so that, with regard to this and many other remedies, it is impossible to say how far the benefit results from the remedy, or is due to the diet. Of all the remedies I have tried, the old tincture of

sesquichloride of iron has, I think, been of the most use. I give from ten minims to half-a-drachm, two or three times a day, in infusion of quassia, and make the patient continue taking the medicine for months. Under its use, I have found in many cases, that the strength improves, and the patient has gained in weight. Cod-liver oil is of service in some cases.

Sugar has been given in large quantity in diabetes, and, as would be supposed, has been found worse than useless.

314. Alkalies have been given in diabetes without decided benefit. I have given large doses of liquor potassæ (ʒiij per diem) without any alteration in the quantity or density of the urine. Vichy water is a very favorite remedy with some, and this and other alkaline waters are exceedingly grateful to the patient. For this reason they may always be ordered, but I doubt if any real effect is produced upon the disease by their use. Gunzler states that bicarbonate of soda reduces the quantity of sugar.

315. Alcohol is said to increase the sugar, but moderate quantities of brandy or whiskey seem to be of service in some cases. I am accustomed to order two or three ounces of whiskey daily, if the patient is weak. I have never seen any bad effects resulting, and many cases have improved while taking this stimulant.

316. Rennet and Pepsin have been given in diabetes. Dr. James Gray ("*Glasgow Medical Journal*," Vol. IV.) states that, of twenty-eight persons treated by rennet, seven 'completely recovered,' but they were also placed upon a restricted diet. Dr. Roberts tried rennet, but although the patient improved while taking it, he improved quite as rapidly before he commenced taking this remedy. ("*Brit. Med. Journ.*," Nov. 17th, 1860.)

According to Leubuscher, the quantity of urea, chloride of sodium, and sugar, were increased by the administration of pepsin, and Dr. Parkes also found that this substance increased the sugar. On the contrary, in one case in which I tried it, benefit resulted, but then there was some dyspepsia, and I thought that the diet was imperfectly assimilated. I have not had an opportunity of trying the effect of pepsin in a very bad case of diabetes, but, in various conditions in which the digestive power of the stomach is impaired,

either temporarily or permanently, I have used it with the greatest advantage. Really good pepsin has not yet had a fair trial in this disease.

Many practitioners doubt the efficacy of pepsin in any case, and some consider it perfectly useless. I believe that such conclusions have been arrived at from bad pepsin having been used. Some years ago (1856), I made some experiments in connection with the action of artificial digestive fluids, and found that, by the following simple method, a very powerful digestive powder, almost tasteless and inodorous, could be readily obtained from the pig's stomach. The pepsin prepared according to the following method is more active than any of the other preparations now in use. I have used it very frequently during the last six years, and it is well known to many other practitioners.

Preparation of Pepsin.—The mucous membrane of a *perfectly fresh* pig's stomach is carefully dissected from the muscular coat, and placed on a flat board. It is then cleansed with a sponge and a little water, and much of the mucus, remains of food, &c., carefully removed. With the back of a knife, or with an ivory paper-knife, the surface is scraped very hard, in order to press the glands and squeeze out their contents. The viscid mucus thus obtained contains the pure gastric juice, with much epithelium from the glands and surface of the mucous membrane. It is spread out upon a piece of glass, so as to form a very thin layer, which is dried at a temperature of 100° over hot water, or in vacuo over sulphuric acid. When dry it is scraped from the glass, powdered, and kept in a stoppered bottle. A good digestive fluid may be made as follows:—

Of the powder	5 grains.
Strong hydrochloric acid	18 drops.
Water	6 ounces.

The fluid may be filtered easily, and forms a perfectly clear solution, very convenient for experiments on artificial digestion, or as a medicine.

The pepsin may be taken in doses of from three to five grains made into a pill with a little glycerine, and taken about twenty minutes before a meal, with ten drops of dilute hydrochloric acid in a wine-glassful of water, or infusion of quassia; or the powder may be mixed with the salt taken with the meals, or sprinkled upon the meat or on bread and butter, as it is tasteless and inodorous.

I have kept this pepsin in a well-stoppered bottle for three years without its active powers being in any way impaired. Four-fifths of a grain of this pepsin, with ten drops of diluted hydrochloric acid and an ounce of water, dissolve 100 grains of hard-boiled white of egg. ("*Archives of Medicine*," Vol I., pp. 269, 316.)

It is prepared by Messrs. Bullock & Reynolds, 3, Hanover Street, W. It costs a shilling a drachm, which may be divided into fifteen or twenty doses.

ALCAPTON.

317. Alcapton.—Bödecker has found in the urine of a patient a substance which possesses many of the reactions of sugar. This is termed alcapton. It is of a pale yellow colour, and does not crystallise. It contains a large quantity of ammonia. It reduces copper, like sugar, but does not reduce oxide of bismuth, nor is fermentation excited in it by yeast. Urine containing it becomes of a brown colour upon exposure to the air, if an alkali be present, without the application of heat. This change occurs if potash be added. *Sugar and potash* change colour only when the solution is boiled.

Alcapton was separated by Bödecker from the urine by the following process:—After precipitation with acetate of lead, the mixture was filtered, and the solution mixed with tribasic acetate of lead, avoiding excess. The precipitate was washed, suspended in water, and decomposed by sulphuretted hydrogen. The solution filtered from the sulphuret of lead was evaporated to dryness over the water bath, and the residue extracted with ether. The alcapton remained after the ether had evaporated. (Bödecker: Zeitschrift. f. rat. Med. VII., 128; "*Ann. Ch. Pharm.*," Jan., 1861; Bowman's "*Medical Chemistry*," edited by Prof. Bloxam, p. 51.) Alcapton was found in the urine of an infant by Dr. Johnson, his attention being called to it by the brown stains on the linen (quoted in Bowman's "*Med. Chem.*," by Bloxam, p. 52).

LEUCINE.

318. Leucine ($C_{12}H_{13}NO_4$) occasionally occurs as a deposit from the urine; but more generally it is held in solution, and can only be obtained by concentration of the fluid, when it crystallises out in

the form of small spherules, which are composed of acicular crystals which radiate from a common centre. This substance has of late been found in many of the solids and fluids of the animal body. It is not very soluble in water (one part in twenty-seven), but more so in alcohol. It crystallises from aqueous solutions, for the most part in spherical masses, which exhibit a radiated arrangement. From alcohol, leucine is deposited in the form of pearly scales, somewhat resembling cholesterine; but these are composed of small spherules. Dry leucine can be sublimed without change. Leucine has been found in the saliva, pancreatic juice, and in the pulmonary tissue of the ox (Cloëtta, "*Chemical Gazette*," 1856, p. 61). Frerichs and Städeler have detected leucine in the blood, urine, and bile of patients suffering from typhus, small-pox, and other exanthemata. Dr. Thudichum found leucine in the urine of a man whose liver yielded a large quantity of it ("*Treatise on the Pathology of the Urine*," 1858). It was obtained by concentrating the urine. This substance is probably formed in the liver. In certain diseases, it is to be detected in very considerable quantity. Crystals of leucine may often be seen in sections of livers of patients who have died of jaundice. Frerichs has given several figures of leucine crystals in the liver, and also in the urine ("*Pathologisch-Anatomischer Atlas zur Leberkrankheiten*," von Dr. F. T. Frerichs, Braunschweig, 1858). It is said to occur especially in the urine of patients suffering from acute yellow atrophy of the liver. I have detected leucine in the urine in cases of chronic wasting of the liver accompanied with jaundice.

No satisfactory tests for leucine are yet known. If it can be obtained pretty pure by repeated recrystallisation, the dry leucine may be sublimed. The sublimate, composed of aggregations of rhombic plates, could not be mistaken for anything else. Urate of soda and many other substances crystallise in spherical globes, like leucine. Crystals of this form, however, which are soluble in alcohol, and again crystallise in spherules from an aqueous solution, can hardly be anything but leucine. This substance cannot be recognised by the form of the crystals alone.

319. On Obtaining Crystals of Leucine from the Urine.— The extractive matters often interfere with the crystallisation of the leucine from urine, and the concentrated extract often remains for

days without undergoing any change. Frerichs ("*Klinik der Leberkrankheiten*," Band I., s. 221) recommends that the concentrated urine should be digested for some time with cold absolute alcohol. By this means, the extractive matters are gradually dissolved out. The residue is then to be treated with boiling spirits of wine; and leucine crystallises out as this solution cools. It may be purified by recrystallisation. The extractive matter may be in great part separated by precipitation with acetate of lead. If much leucine is present it crystallises if the urine be concentrated. Crystals of leucine are represented in Plate XIV., Figs. 69, 70. The crystals at *a*, were crystallised from water. The rest were obtained from an alcoholic solution.

Tyrosine.

320. **Tyrosine** ($C_{18}H_{11}NO_6$) has been detected in the urine of typhus fever by Frerichs and Städeler. Like leucine, it is probably produced in the liver. It has been detected in this organ by Frerichs, Dr. Thudichum, and many other observers. It has been extracted from several animal fluids. Tyrosine crystallises in long white needles, and is very slightly soluble in cold water. Crystals of tyrosine are represented in Plate XIV., Fig. 71. It is dissolved by boiling water, alcohol, ether, the mineral acids, and alkalies. It may be prepared by boiling horn, feathers, or hair, with sulphuric acid, for forty hours. The dark brown liquid is to be made alkaline with milk of lime, warmed, and then filtered. Sulphuric acid is added to neutralisation, and crystals are deposited upon evaporating the liquid. A very delicate test for this substance has been proposed by Hoffman. A solution of nitrate of protoxide of mercury, nearly neutral, is to be added to the solution suspected to contain tyrosine. If this body be present, a reddish precipitate is produced, and the supernatant fluid is of a very dark rose colour. Frerichs' tests for tyrosine are as follows:—The matter supposed to be tyrosine is mixed with sulphuric acid in a small capsule. After the lapse of half an hour water is added. The solution is then boiled, and excess of carbonate of lime added. To the filtered solution a few drops of a solution of perchloride of iron which is free from acid is added. A dark purple colour is produced if tyrosine is present. In order to obtain tyrosine from urine it is necessary to add a solution of acetate

of lead until a precipitate is no longer produced. Sulphuretted hydrogen is passed through the filtered liquid. The sulphuret of lead being separated by filtration, the clear solution may be concentrated by evaporation, when tyrosine, if present, will crystallise out. Tyrosine crystallises in long white needles, which are aggregated to form brush-like masses. De la Rue found tyrosine in the cochineal insect. This is doubtless one of the substances resulting from the disintegration of albuminous substances. I have found it in considerable quantity in urine which contained much uric acid, and had been left to stand in a warm place for many weeks.

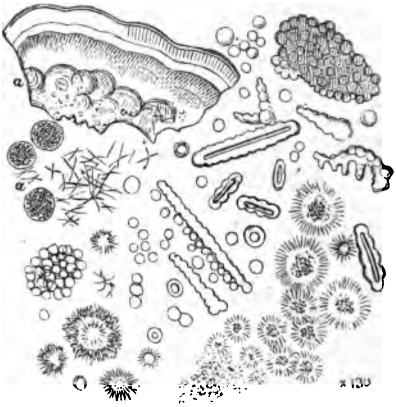
Leucine and tyrosine were detected by Dr. Harley in the urine of a dog four days after dog's bile had been injected under the skin. ("*On Jaundice*," p. 96.)

Inosite.

321. Inosite ($C_{12}H_{12}O_{12}+4HO$) was discovered by Scherer in the juice of muscle, after the creatine and creatinine had been separated. It is termed muscle-sugar, and may be obtained in the form of colourless prismatic crystals, which are efflorescent. Crystals of Inosite are represented in Plate XI., Fig. 60. Inosite does not reduce the oxide of copper to the state of suboxide, as is the case with diabetic sugar and grape-sugar. It tastes sweet, and has the same composition as the latter substance. Inosite may be detected by evaporation nearly to dryness in a platinum basin, when, if a little ammonia and chloride of calcium be added, a rose colour is produced, especially if the mixture be again concentrated by evaporation.

Cloëtta has found inosite in the urine in Bright's disease, but has failed to detect it in the healthy secretion. He has discovered it in the lungs, liver, spleen, and kidneys. The lungs also contain traces of uric acid, taurine, and leucine. M. Hohl has lately recorded a case of diabetes in which a large quantity of inosite was obtained from the urine ("*Gazette Hebd. de Méd. et de Chir.*," 1859, p. 221; "*Journal de la Physiologie*," No. vi., p. 344). In this case, the proportion of sugar gradually diminished, and at the same time the quantity of urea excreted became less, while the inosite gradually increased in amount until upwards of *three hundred grains* of this substance were passed in the twenty-four hours. This observation is one of great interest in connection with the pathology of diabetes.

Fig. 69.



§ 319

Fig. 70.

§ 319

Fig. 71.

§ 320

Fig. 71*.

§ § 323, 411

Acetone.

322. **Acetone** ($C_6H_6O_2$).—Dr. Petters, at the suggestion of Dr. Lerch, of Prague, sought for acetone in the urine of a case of diabetes, and discovered it both in the blood and urine (*Viertel-jahrsch. für die Pract. Heilkunde*, Prag, 1857, Vol LV., p. 81). The peculiar smell of diabetic urine is to be attributed to the presence of acetone, according to this observer.

Cystine.

323. **Cystine** ($C_{12}H_{12}N_2S_4O_8$) is found in a state of solution in the urine in some cases, although it more usually occurs as a deposit. We shall, therefore, consider it more particularly under the head of urinary deposits. Julius Müller ("*Archiv. der Pharmacie*") obtained some urine from a boy 6½ years of age, which contained cystine in solution. The urine was alkaline. The cystine was precipitated in the crystalline form by the addition of excess of acetic acid. Thoel mentions the occurrence of cystine in the urine of many members of the same family (Liebig and Wöhler's "*Annalen*," 1856). Crystals of cystine are represented in Plate X., Figs. 1, 2, 3, 4, of "*Illustrations of Urine, Urinary Deposits, and Calculi*;" and in Plate XIV., Fig. 71* of this work.

Taurine ($C_4H_7NS_2O_6$) has been found in the urine of jaundice.

Allantoin ($C_8H_6N_4O_6$) has never been detected in human urine, but it was present in the urine of a dog into whose lungs oil had been injected by Frerichs and Städeler. It may, perhaps, exist in the urine of young children (Parkes). It is always present in the urine of calves while sucking, but afterwards it is replaced by hippuric acid.

Guanin, Sarkosin, and Kynurenic Acid (the peculiar acid of the urine of the dog), have never been positively detected in the urine of man (Parkes).

Hypoxanthin ($C_{10}H_4N_4O_2$), or Sarkine, is found with Xanthine (§ 401). It has been detected by Scherer in the urine in Leucocythemia.

I have ventured to occupy some time in the consideration of the characters of certain substances the presence of which in urine has only very recently been demonstrated. Probably, when the various materials removed in this excretion shall have been more thoroughly investigated, and when we know more relating to the precise conditions under which they are formed in the animal economy, the treatment of many diseases will be placed on a sounder basis, and we shall be able to relieve sufferings and prevent the progress of morbid changes over which we have now very little control. It is true, there are many who consider all this minute scrutiny and scientific investigation as useless, or at least unnecessary and unpractical. This is a state of mind which it is difficult to understand; for it seems obvious the more minutely our investigation of diseased processes is carried out, the more we shall know about them, and the better able shall we be to suggest plans of treatment to combat the abnormal changes. That scientific work will ultimately lead to great practical results in treatment is certain; and every one must feel that any amount of time devoted to original research is most usefully and advantageously spent.

CHAPTER XIII.

URINE IN DISEASE. 1. SUBSTANCES FLOATING ON THE SURFACE OF THE URINE, OR DIFFUSED THROUGH IT, BUT NOT FORMING A VISIBLE DEPOSIT. *Thin Pellicle formed upon the Surface of Urine—Opalescent Urine—Opalescence produced by Vibriones—Milk in Urine.* DIFFERENT STATES IN WHICH FATTY MATTERS OCCUR IN URINE. *Chylous Urine—Mr. Cubitt's Case—Dr. Bence Jones' Case—Dr. Waters' Case—Dr. Priestly's Case—Dr. Carter's Cases—Analyses of the Urine—Microscopical Characters of the Deposit—Of the Treatment of Cases of Chylous Urine—Of the Nature of Chylous Urine—Composition of Fatty Matter passed in Cases of Fatty Degeneration of the Kidney—Cholesterine in Urine—Cholesterine said to be obtained from the Urine in other Diseases—Kiestein.* OTHER FORMS IN WHICH FATTY MATTER OCCURS IN URINE. *Urostealith—Fluid Yellow Fat—Fatty Matter in Rabbits' Urine—Erroneous Observations connected with the Presence of Fatty Matter in Urine.*

324. Thin Pellicle formed upon the Surface of Urine.—Several different substances are found from time to time floating on the surface of urine; but, for the most part, these are merely buoyed up by a thin pellicle, which is probably formed by the action of the air on the urine, leading to the decomposition of some of its constituents. This often causes the precipitation of the phosphates mixed with organic matter in the form of a thin pellicle. Triple phosphate is also deposited in the pellicle, in a crystalline form, some of the crystals being exceedingly minute, but still exhibiting their well known characters. A similar pellicle may always be formed, if urine be somewhat concentrated by evaporation; but in this case a large

quantity of urate of soda is entangled in it. The urate crystallises in the form of small spherical masses, from all sides of which little spicules project (Plate XIX., Fig. 92).

Fatty matter is often found floating upon the surface of urine, especially when it has fallen in accidentally. One form of fatty matter has been described under the name of kiestein, and this it has been said is constantly present in the urine of pregnant women.

Urates occasionally accumulate upon the surface of urine, but present nothing peculiar for remark.

325. Opalescent Urine.—The turbidity or opalescence of urine is most frequently due to the presence of urates in an exceedingly minute state of division. The precipitate may be so fine and so light that it will not sink to the bottom and leave a clear supernatant fluid. The urine is perfectly clear when passed, but becomes turbid afterwards. Upon the application of a gentle heat, the turbidity is instantly removed. In urine of high specific gravity, many substances are held in suspension which would form a deposit in fluids of the usual density. It is not uncommon to meet with pus or blood thus diffused through the urine. If mucus be present in large proportion, many substances which usually form deposits will be buoyed up as it were, and evenly diffused through the fluid, although generally these substances subside more or less.

Opalescence produced by Vibriones. Some specimens of urine become decomposed very soon after they have been passed; others are voided in a state of incipient decomposition. Such specimens are found turbid, and look as if they had been mixed with a very small quantity of milk. Upon microscopical examination, it will be found that this turbidity depends entirely upon multitudes of some of the lowest organisms, consisting of different forms of fungi and other little elongated bodies termed vibriones, which are considered by some authorities to be animals, while others class them with vegetables. There can be little doubt as to their vegetable nature.

Milk is often added to urine, for the purpose of deceiving us, and is of course diffused through the fluid, the degree of opalescence varying according to the quantity of milk added. Milk can always be detected upon microscopical examination by the presence of the numerous oil-globules, and by the circumstance of the milky fluid becoming quite clear after agitation with a little ether and a few

drops of acetic acid or carbonate of potash, which will dissolve the envelopes of casein around the globules, and thus the oily matter becomes exposed to the solvent action of the ether. By the addition of a little acetic acid, the casein of the milk is precipitated.

It is astonishing with what pertinacity some patients adhere to the statement that the milk which we detect has really been passed in the urine, as they state, although its true nature has been demonstrated most conclusively. A case was brought under my notice, some time since, of a young girl, who convinced all her friends that she passed more than a pint of milk and water a day in the form of tears! The fluid was proved to be milk, and in it were found epithelial cells from the mouth. The patient admitted afterwards that she had imposed upon her friends.

Oil, it must be remembered, is often found in urine in the form of free globules, especially after the use of an oiled catheter. Butter and other fatty matters sometimes fall into the urine accidentally. (*See also* § 87.)

Fatty Matter in Urine.

326. Different States in which Fatty Matter occurs in Urine.—The different conditions in which fatty matter has been found in urine, may be summed up under the following heads:—

1. *In a molecular state*, as in chylous urine.

2. *In the form of globules*, as when oil, fatty matter, or milk, have been added to urine.

3. *In the form of globules* (*a*), free in the deposit (*b*), enclosed in cells (fat-cell), or (*c*) entangled in casts.

4. *Dissolved* in small quantity by other constituents, so that its presence can only be detected by chemical examination.

5. *In the form of concretions* (urostealith, as described in one solitary case by Heller).

6. *In a fluid state*, of which two cases are reported by Dr. C. Mettenheimer.

Chylous Urine.

327. Chylous Urine.—The most important substance which gives to urine an opalescent appearance, and at the same time causes it to resemble milk, is fatty matter in a very minute state of

division—in a *molecular state*, as it is termed. Such urine, under the microscope, is seen to contain a considerable quantity of the most minute particles, which exhibit molecular movements, and a few small granular cells very much like white blood or chyle corpuscles are often observed (*See* Plate XV., Fig. 72). The minute particles are not altered by a moderate heat, but are dissolved in great measure, though often not entirely, if the urine be agitated with ether. Urine possessing these characters is termed chylous urine. Chylous urine often contains a little blood which produces a pinkish hue. Cases of chylous urine are very seldom met with in this country, but they are comparatively common in Brazil, Cuba, the West Indies, the Mauritius and India.

The following interesting case occurred in the practice of my friend Mr. Cubitt of Stroud, to whom I am indebted for the notes, and also for the specimens of urine which I analysed.

328. Mr. Cubitt's Case of Chylous Urine.—"Mrs. S., aged 50, native of Norfolk, in which county she has always resided, has been married twenty-nine years, and has had five children, the last of whom died in its second year. The youngest now living is 20. The catamenia ceased at 43.

"Till within the last four years, she has usually enjoyed good health, but at that time had a severe attack of influenza. She continued more or less out of health during the six or nine following months, and soon after this period her urine assumed a milky appearance, which character it has retained up to the present time (November, 1849), except at intervals of unfrequent occurrence and of short duration. The disorder would seem to have been gradually progressive, as the urine, which was at first only turbid and opalescent, has become by degrees more and more opaque, so that when I saw it, the unassisted eye could not distinguish between it and milk; moreover, after the lapse of a few days, a rich kind of cream rises to the surface. It is almost entirely free from any urinous odour, and has a faint, sweetish smell, something resembling that of ripe apples. In the mean time, the general health has been more and more failing, and the digestive functions imperfectly performed; the patient has complained of loss of appetite, pain at the epigastrium after eating, slight headache with nausea, palpitations, and other dyspeptic symptoms. She has been losing flesh, suffers from

pain in the back and loins without tenderness, from aching of the limbs, incapability of exertion, and other evidences of general debility; but still when the duration of the disease is taken into account, the general health may, upon the whole, be said to have suffered little. She states that, throughout the affection, fatigue, whether of mind or body, unusual exertion, excitement, late hours, distress, anxiety, immediately render the milky character of the urine more marked. She has been under the care of several medical men, as well as of some professed quacks (none of whom have ever examined the urine), without benefit; nevertheless, she has found that, for the time, brandy and isinglass, or compound spirits of lavender, have never failed to clear the urine, but without at all improving the general health. She seems to derive *temporary relief from all kind of stimulants.* Occasionally, and without any apparent cause, the urine reassumes its ordinary appearance, but this is of rare occurrence, and its duration never exceeds two or three days. At no one time has she passed milky urine *during the day.* It is only the urine passed in the morning, after the night's sleep, which has ever presented a milky character. Occasionally, this urine settles down into a tremulous jelly, which takes the shape of the containing vessel, and more than once this spontaneous coagulation has taken place within the bladder itself; and in consequence of the impaction of small masses in the urethra, the patient has suffered from temporary retention of urine. She has tried various kinds of diet, but without any visible effect upon the urine. The quantity secreted appears normal, and there is no unusual frequency of micturition. The appetite has never been inordinate, or the thirst unnatural; the bowels are inclined to be costive. There is nothing remarkable about the state of the skin. She has suffered a good deal from pain in the back and loins, but there is no tenderness in this locality, and the uneasiness seems to depend upon exertion, and appears to be connected with general debility. There has never been any dropsy, and she has suffered from no cardiac or pulmonary symptoms, but such as may be accounted for by the dyspepsia; but I have not had an opportunity of examining the chest. She has never had severe headache, vertigo, vomiting, or other cerebral symptoms. Has never had rheumatism, fever, or any inflammatory attack, has not been salivated, and has no reason to suppose she has suffered from exposure to cold. At the time when I saw her, the

tongue was slightly furred, pulse 70, small and soft, respiration 20, and the skin cool; but there was a haggard appearance about the countenance, and a dark circle around the eyes, with slight bagging of the skin in this situation."

Mr. Cubitt inquired as to this patient's state in April, 1857, and informed me that occasionally she passed chylous urine, but only for a short time. The symptoms seem to have become less marked. She has been taking no medicine, and latterly has been in better general health than for several years past.

329. Analyses of Chylous Urine.—The first specimen of urine was passed in the morning (*Analysis* 58). It was perfectly fluid, and had all the appearance of fresh milk. It had neither a urinous smell nor taste. Upon the addition of an equal volume of ether it became perfectly clear; but when the ether was allowed to evaporate by the application of a gentle heat, the fatty matter could be again diffused, by agitation, through the urine, which regained its milky appearance, although it appeared rather more transparent than before the addition of the ether. Upon examination, however, by the microscope, instead of the minute *granules* visible in the first instance, *numerous large and well-defined oil-globules* were observed.

Specific gravity, 1013. *Reaction*, neutral.

A little of the urine was evaporated to dryness. The dry residue was very greasy to the touch. It was treated with ether; and, upon evaporating the ethereal solution, a considerable quantity of hard and colourless fat was obtained.

Analysis 58.

The urine was found to contain in 1000 parts—

Water	947·4	
Solid matter	52·6	
Urea	7·73	
Albumen	13·00	
Extractive matter with uric acid	11·66	
Fat insoluble in hot and cold alcohol, but soluble in ether	9·20	13·9
Fat insoluble in cold alcohol	2·70	
Fat soluble in cold alcohol	2·00	
Alkaline sulphates and chlorides	1·65	
Phosphates	4·66	

The second specimen (*Analysis* 59) was passed during the same day. It was slightly turbid, but contained a mere trace of deposit, consisting of a little epithelium, with a few cells larger than lymph corpuscles, and a few small cells, probably minute fungi. Not the slightest precipitate was produced by the application of heat, or by the addition of nitric acid.

Specific gravity, 1010. *Reaction*, very slightly acid.

Analysis 59.

In 1000 parts it contained—

Water	978·8	
Solid matter	21·2	
Urea	6·95	
Uric Acid	15	
Extractive matter	7·31	
Fatty matter	0	
Alkaline sulphates and chlorides	5·34	
Alkaline phosphates	1·45	1·60
Earthy phosphates	·15	

The presence of so large a proportion of fatty matter, perhaps, combined with the albumen (13·9 grains) in the first specimen, and its complete absence in the second, which was passed only a few hours afterwards, is very interesting, and bears upon the pathology of this strange condition.

The proportion of the constituents in 100 grains of the solid matter of these two specimens of urine, is given in the following table. 60 is the chylous, 61 the clear specimen:—

	60	61
Solid matter	100·00	100·00
Urea	14·69	32·78
Albumen	24·71	—
Extractive matter, uric acid	22·17	35·18
Fatty matter	26·43	—
Alkaline sulphates and chlorides	3·14	25·18
Phosphates	8·86	7·54

330. Microscopical Characters of the Deposit.—The slight deposit which formed after the chylous urine had been allowed to stand for some time in a conical glass vessel, consisted of a small quantity of vesical epithelium, and some small slightly granular circular cells resembling chyle or lymph corpuscles.

No oil-globules could be detected upon the surface of the urine or amongst the deposit, and the fatty matter, which was equally diffused throughout, was in a molecular or granular form. By examining the urine with the highest powers, only very minute granules could be detected. These exhibited molecular movements. Indeed, it may be said that the microscopical characters of this urine closely resembled those of chyle. (Plate XV., Fig. 72.)

Only a few of the granular cells could be discovered in the clear specimen, in which there was scarcely any visible deposit.

In a case which occurred in the practice of Mr. Gossett, and which is related by Dr. Golding Bird, an alternation in the character of the urine similar to that noticed in the present case, occurred. As in this case, the urine which was passed in the morning was *chylous*, while that secreted some hours afterwards was *clear*, *pale*, *and transparent*. The clear specimens, however, contained albumen. The chylous specimen which I examined did not coagulate spontaneously, as often occurs in these cases. In the case reported by Dr. Bence Jones, specimens of urine were frequently passed which were perfectly clear.

L'Hèretier, and the late Dr. Franz Simon, of Berlin, state that these specimens of milky-looking urine contain *oil-globules;* but the greater number of authors who have met with such cases have failed to detect oil-globules in the urine. In the instance under consideration they were certainly absent, and the fatty matter existed in a molecular form only. In Dr. Bence Jones' case, *oil-globules* were found in one or two instances; but in other specimens the fatty matter was present in a molecular state. Dr. Waters states that *oil-globules* were present in the urine in a case he had under his care, and that the urine contained mucus and pus-corpuscles.

In true cases of chylous urine, the fatty matter, in a molecular state, seems to escape at once into the urine; while in cases of fatty degeneration of the kidney, in which *actual globules* are observed, the fatty matter exists in the interior of the cells, where it remains a sufficient time to become converted into distinct oil-globules.

Globules thus formed may afterwards become separated from each other, and may appear in the urine as free oil-globules. Such *oil-globules* make their appearance in all cells which have been kept for some time in 'preservative fluids.' The change in question is unfortunately too familiar to microscopists. It would seem to show that the oil-globules result from the decomposition of matter which, under the conditions present in the healthy living body, would be resolved into perfectly soluble constituents, and it is not improbable that when this change occurs in cells in the living body, it is due to diminished activity of the chemical changes, and especially to diminished oxidation.

After chylous urine has been allowed to stand for some time, the granular fatty matter may become aggregated in masses, so as to form distinct oil-globules.

331. Dr. Bence Jones' Cases.—In a case of albuminous and fatty urine, reported by Dr. Bence Jones ("*Medico-Chirurgical Transactions*," Vol. XXXIII.), oil-globules and streaks of oil were detected upon the surface of the urine which was passed in the morning, by microscopical examination. In two other specimens passed later in the day, fatty matter in a molecular form, but no oil-globules, was discovered. Upon standing, a coagulum formed in the urine. These specimens contained about 50 grains of solid matter in 1000 of urine. The patient was a Scotchman, aged 32. His work was hard, and he was subject to privations. The urine was first observed to be thick and white about Christmas, 1848; and at this time, the chief symptom from which he suffered, was acute pain in the loins.

Lehmann is, as far as I know, the only observer who states that chylous urine never owes its opacity to fat ("*Physiological Chemistry*," Vol. III., p. 544). I have now seen and heard of several cases, and in *every one* the opacity was due to *fatty matter*. Authorities generally are quite agreed upon this point; but some state that the fat is sometimes in the form of *globules*. In the cases I have seen, it was in a *molecular state* only.

The following are two analyses of the urine in Dr. Bence Jones' case. The first was made on October 19th, and the second was passed some time afterwards, on the same day on which the patient was bled.

Analyses.

	62	63
Water	955·58	943·13
Solid matter	44·42	56·87
Albumen	14·03	13·95
Urea	13·26	24·06
Fatty matter	8·37	7·46
Saline residue	8·01	10·80
Loss	·75	·60

The chylous urine contained blood-corpuscles. The serum of the blood was not milky, but the blood contained in 1000 parts 240·03 of solid residue, which contained of fatty matter ·62; fibrine, 2·63; blood-globules, 159·3; solids of serum, 78·1.

Dr. Bence Jones showed, in some valuable experiments on this case, that during complete rest, albumen was not passed. ("*Phil. Trans.*," 1850.)

The urine was not chylous from February 14th, 1850, to October 4th, 1851, when it was again slightly chylous. The beneficial change was entirely attributable to gallic acid. At first, twenty grains three times a day were given, but this was afterwards diminished.

Dr. Bence Jones mentions another case of a gentleman, aged 40, who passed the greater part of his life in the West Indies. The chylous condition of the urine was increased both by mental and bodily exertion. The urine was sometimes clear for several days together, sometimes white after dinner, and clear all the rest of the day. It was more frequently chylous after *animal* than after *vegetable food.*

332. Dr. Waters' Case.—Dr. Waters, of Liverpool ("*Medico-Chirurgical Transactions,*" Vol. XLV., for 1862), reports the case of a young seaman, a native of Bermuda, in whom retention of the urine was caused by the coagulation of chylous urine within the bladder. The urine had the usual characters of chylous urine, but coagulated into a tremulous mass exactly resembling *blanc-mange.* The urine contained blood-corpuscles. Analysis 64 shows the composition of the urine in Dr. Waters' case of chylous urine. It was made by Dr. Baker Edwards, of Liverpool. Specific gravity, 1012.

Analysis 64.

Water	967·3
Solid matter	32·7
Urea	6·0
Albumen, with traces of uric acid	6·0
Fat	9·9
Vesical mucus	4·5
Animal extractive	4·1
Fixed alkaline salts	2·0
Earthy salts	·2

333. Dr. Priestley's Case.—The patient was a boy who was only 11 years of age. ("*Medical Times and Gazette*," April 18th, 1857.) He was born at the Cape of Good Hope, and was taken as a child to the Isle of France, and while there had frequent attacks of hæmaturia and chylous urine. The attacks came on at intervals of weeks or months. He was placed, in the autumn of 1855, under the care of Dr. Simpson, of Edinburgh. Various plans of treatment were tried in vain. He was confined to the house, and passed as much as from fifty to fifty-five ounces of chylous urine daily. He gradually became weaker, and died apparently from asthenia. A fortnight before death, the urine lost its milky appearance, and the feet became œdematous. Every tissue appeared bloodless, and there was considerable emaciation. The kidneys were pale, rather larger than natural. Throughout the greater part of both kidneys the epithelium was found to contain numerous oil-globules. Dr. Priestley suggests the possibility that this case of chylous urine may have been associated with Bright's disease.

334. Dr. Carter's Cases.—The observations of Dr. Carter ("*Medico-Chirurgical Transactions*" for 1862, Vol. XLV.) are strongly in favour of the view that chyle obtains *direct* entrance into some part of the urinary channels. In three cases reported by him, there was accumulation in the lymphatics. In the first the chyle was occasionally discharged from the cutaneous surface, the urine being unaffected.

The opening in the lymphatic vessel, from which the chyle escaped, was situated a few inches below Poupart's ligament, and sometimes a pint could be collected in a day.

In the second case there was an external discharge of *chyle*, and the urine was frequently *chylous*. The third was a case of *chylous urine* without any external discharge of chyle.

These cases prove the existence of a dilated condition of the lymphatic vessels. The dilatation clearly extending as high as the thoracic duct, thus allowing the chyle to pass from this tube into the lymphatics. In such a case the tube would be stretched so as to render the valves useless.

OF THE TREATMENT OF CHYLOUS URINE.

335. Of the Treatment of Cases of Chylous Urine.—Various plans of treatment have been tried in cases of chylous urine, but without very satisfactory results. Astringents have proved useful in many instances; and in one of Dr. Bence Jones' cases, the pressure of a tight belt "relieved the pain, and rendered the urine slightly less chylous."

Dr. Prout found that in some of his cases temporary relief resulted from the use of the mineral acids and astringents, as alum and acetate of lead. Opium also arrested some of the symptoms for a while. Dr. Bence Jones has tried a variety of remedies, but the greatest advantage seems to have been derived from the use of astringents. Tannic acid, acetate of lead, and nitrate of silver, were employed. Matico afforded some relief, but the most valuable remedy in Dr. Bence Jones' hands was gallic acid. Its good effects were probably due to its astringent properties, and not to any specific action. The chylous character of the urine and the albumen disappeared two days after the commencement of the use of this drug; and in one case the patient seems to have been cured by its long continued use. (For the results of a daily examination of the urine for some weeks while the patient was on gallic acid, *see* "*Phil. Trans.*," 1850.)

In Dr. Priestley's case, the gallic acid caused such nausea that it was considered expedient to abandon its use.

Gallic acid was also tried by Dr. Goodwin of Norwich, in a case which came under his care. He says—"Gallic acid appeared to exert great influence in restraining the milky appearance of the urine. The patient took it for about nine months in 1855 and 1856; and I found his water perfectly normal in colour after six months

steady use of it in doses of half a drachm three times a day. He then discontinued its use, and went to work. In four or five days, the same milky appearance presented itself, and was again removed by taking the gallic acid. He could at any time render the urine nearly normal in appearance by taking this drug; but it was necessary to avoid hard work. He only complained of occasional dimness of sight and deafness; but it was not easy to make out to what cause these symptoms were due. He left off attending the hospital in September last, when my note is as follows:—Has not had any gallic acid for three weeks, and the urine is now slightly opaline in appearance. Specific gravity, 1010; the temperature of air was about 50°. He passes seven pints and a half daily on the average. It does not coagulate with heat or nitric acid, or both combined." Dr. Goodwin has not been able to ascertain anything of the further history of the case.

In Dr. Waters' case gallic acid was given in doses commencing at 30 grains a day, gradually increased to 135 grains a day, and then gradually reduced. The patient was under treatment less than nine weeks and got quite well. His weight increased from 8 stone 6 lbs., to 10 stone 6 lbs. Four months after his discharge from the hospital he continued in good health. There was no albumen or fatty matter in the urine.

Of the Nature of Chylous Urine.

336. Of Cases of Chylous Urine.—The very large quantity of fatty matter present in the first specimen of urine (Analysis 58), and its total absence in the urine passed only a few hours afterwards (Analysis 59), is remarkable in Mr. Cubitt's case, and confirms the conclusions which previous observers have arrived at with reference to this condition; viz., that the fatty matter appears in largest quantity after the absorption of chyle; although in Dr. Bence Jones' case it did not appear to be associated with any fatty condition of the blood. In Mr. Cubitt's case, we may, I think, conclude that there is no organic disease of the kidneys. First, from the absence of any symptoms; secondly, from the microscopical characters of the deposit; and, thirdly, from the fact that albumen was only present when the urine contained the fatty matter.

Many of the patients whose cases are recorded, have suffered from

severe pain in the region of the kidneys; but this may be accounted for by general debility, associated with this condition of urine, as well as on the supposition of the existence of organic disease of the kidneys. Indeed, the pain referred to in this locality, seems to partake more of the character of muscular pain than of pain seated in the kidneys themselves.

No lesion likely to account for the production of the chylous urine has been met with in the *post-mortem* examinations of the cases of this condition which have been made; and most observers consider that the chylous condition of the urine does not depend upon a morbid state of the kidneys. Dr. Elliotson, on the other hand, inclines to the view that the kidneys are to be regarded as the seat of the affection. He gives the history of a very interesting case in the "*Medical Times and Gazette*" for September 19th, 1857.

Dr. Waters, grounding his conclusions upon the apparent effects of treatment in one case, considers that the disease depends upon "A relaxed condition of the capillaries of the kidneys." He thinks that the fibrin, albumen, fat, and blood-corpuscles, simply filter away from the blood-vessels. The results of the two analyses recorded on pages 272, 273, are, however, quite inexplicable upon such a view.

Dr. Carter has remarked, that in some analyses—as, for example, in mine already referred to (p. 272)—the relative proportion of albumen and fatty matter precisely accords with that in chyle, as shown in the following analyses:—

	Rees' Analysis of Chyle. Per 1000.	*My Analysis of Chylous Urine.* Per 1000.
Fatty matter	36·01	13·9
Albuminous matter	35·16	13·0

In both the proportions are nearly equal, but the chyle varies somewhat in composition, there being two parts of albumen to one of fatty matter. Dr. Bence Jones' analysis of chylous urine shows a similar relation existing between the fatty and albuminous matters present.

I have long suspected that the chyle passed into the urinary tract by a course more direct than was usually supposed, and the two concluding paragraphs which are left, with the exception of the words in brackets, as in the first edition of this work, clearly show

that I considered it important to search for a *direct communication* between the lacteal vessels and the urinary tract. Dr. Carter seems to have misunderstood my observation, that the "chylous character of the urine was intimately associated with the absorption of chyle." The meaning I intended to convey was, that, after chyle had been undergoing absorption by the *lacteals of the intestine*, the chylous state of the urine was observed in some of the cases recorded.

The cases of Dr. Carter are exceedingly important, and bear, in a most interesting manner, upon the pathology of chylous urine. There remains, however, the fact to be demonstrated, that coloured fluid injected into the thoracic duct will pass into the pelvis of the kidney, ureters or bladder, in this disease. Post-mortems occur so rarely in this country, that it may be long before an opportunity of making the experiment offers itself.

Upon reviewing the chief points in these and other cases, one is led to conclude that the condition does not depend upon any permanent *morbid* change in the secreting structure of the kidney, and that the chylous character of the urine is intimately connected with the absorption of chyle (by the lacteals ramifying on the intestines). The debility and emaciation show that the fatty matter, albumen, and other nutritive substances, are diverted from their proper course, and removed in the urine, instead of being appropriated to the nutrition of the system. Whether these materials, are separated from the blood by the kidneys, or find their way to these organs by some more direct course, cannot now be decided.

I trust that practitioners who have opportunities of examining many of these cases in the West Indies, will afford us assistance in endeavouring to ascertain the nature of this curious condition. Careful reports of the most marked cases are much to be desired. In *post-mortem* examinations, the serum of the blood should be collected and allowed to stand, in order to see if it were milky or not. The state of the mesenteric glands, lacteals, and receptaculum chyli, should be particularly examined, and it would be desirable to inject the thoracic duct, first with transparent fluid injection, and afterwards distend it with a little strong size, when the course of the absorbent trunks might be traced, and, if necessary, parts subjected to microscopical examination.

Of Cholesterine in Urine.

337. Composition of Fatty Matter passed in Cases of Fatty Degeneration of the Kidney.—Some years ago (1850), when examining the fatty matter which accumulates in the epithelial cells passed in the urine in great number in some cases of fatty degeneration of the kidney, I was surprised to find that it contained a considerable quantity of cholesterine. The only cases in which cholesterine seems to have been detected in urine, are those which are referred to in Simon's "*Animal Chemistry*." Gmelin is said to have found cholesterine in the urine in a case in which the flow of bile was impeded; and Möller twice detected it in kiestein, the film which rises to the surface of the urine of pregnant women, and contains sometimes much fatty matter. (Casper's "*Wochenschr.*, Jan. 11—18, 1845; quoted in Franz Simon's "*Animal Chemistry*," Vol. II., pp. 313, 333.) It is not stated, however, in these cases, if the crystalline form of the crystals was made out; nor is it certain that the matter referred to was cholesterine at all.

Other authorities, among whom is Lehmann, state that cholesterine has never been detected in urine.

The first case which I examined was that of John Ryan, a patient in King's College Hospital in 1850, under the care of Dr. Todd. The urine was pale, of acid reaction; specific gravity 1020, and contained albumen. The pale flocculent deposit consisted principally of fat cells.

The deposit from upwards of seven gallons of urine was collected upon a filter. It was dried over a water-bath, and digested in a mixture of alcohol and ether. The solution was filtered, and after being concentrated by evaporation, was allowed to cool. Crystals of cholesterine were found in considerable number. These were subjected to microscopical examination. The fatty matter in this case was composed of at least three distinct forms of fat; but, in consequence of the very small quantity obtained for observation, it was not possible to investigate their characters very minutely. The deposit from this urine contained—

1. A dark brown fat in very small quantity, which was soluble in ether, but insoluble in hot and cold alcohol.

2. A light brown saponifable fat, soluble in hot but insoluble in cold alcohol.

3. A considerable quantity of pure *cholesterine*, which originally existed in the urine dissolved in the other fats.

The next case of fatty degeneration of the kidney submitted to examination was that of a man named Tiedeman, also a patient of Dr. Todd's, in King's College Hospital. The case is published in Dr. Todd's "*Clinical Lectures*" (Case 107). See also "*Archives of Medicine*," vol. I. page 8. The fatty matter obtained from twenty-four pints of urine weighed only ·47 grains, but from this a great number of crystals of cholesterine were obtained by extraction with alcohol.

The deposit of the urine of a third case of fatty degeneration of the kidney has been submitted to examination, and cholesterine has been discovered in this instance also.

In another case in which the deposit had been kept for some time in a preservative fluid consisting of wood-naptha, creasote, and water, the cholesterine had separated spontaneously from the other constituents of the oil-globules, in the form of rhomboidal tablets.

The fatty matter deposited in the kidney in these cases also contains a large proportion of cholesterine; and I have detected the presence of cholesterine in the fatty matter of so many organs in a state of fatty degeneration, as to justify the conclusion that the formation of this substance is intimately connected with the changes taking place in this morbid process.

When cholesterine occurs in the urine, it is always dissolved in other fatty matters, so that its presence cannot be detected except by extraction with alcohol and subsequent crystallisation. It is one of the constant constituents of the minute fat-globules produced in the epithelial cells and casts of the uriniferous tubes, which are so characteristic of this form of kidney-disease.

Surprise has often been excited by observing that oil-globules passed in the urine in these cases, sink to the bottom of the vessel, when we should expect rather to find the fatty matter rising to the surface by reason of its lightness. That the cell-walls and casts are not the sole cause of this subsidence, is proved by the fact that individual globules, quite free from these structures, are frequently found at the bottom of the vessel with the deposit. This subsidence is probably in some measure due to the quantity of the cholesterine entering into the composition of the fatty matter. Crystals of cholesterine sink in fluids of a specific gravity even some degrees above 1000.

338. Cholesterine said to be obtained from the Urine in other diseases.—I have not been able to detect cholesterine in the urine in any other morbid condition than in that above referred to. Although I have at present only searched for it in four cases of fatty degeneration, in consequence of the difficulty of obtaining sufficient quantity of the deposit to work upon, the circumstances which I have enumerated render it very probable that it is a constituent of the fatty matter present not only in the urine in all cases of fatty degeneration of the kidney, but that it is a constant constituent of the fatty matter present in all cells and tissues in a state of fatty degeneration.

It has been stated by some observers, that cholesterine was to be obtained from the urine in several different forms of disease. Dr. Salisbury ("*American Journal of the Medical Sciences*," April, 1863,) states that he detected cholesterine in eighteen specimens of morbid urine, but he does not appear to have tested the crystals he obtained, which in their general form certainly resembled cholesterine. This observer asserts that in diabetic urine be obtained a very large quantity of cholesterine. From a specimen of diabetic urine, which I examined by the process recommended by Dr. Salisbury, I certainly obtained crystals very much resembling plates of cholesterine, but they were *soluble in boiling water*, and were found to consist of hippuric acid. Dr. Salisbury has not stated if the crystals he obtained were insoluble in boiling water, nor has he shown that they consisted of cholesterine. It has not yet been proved that cholesterine is ever excreted in a state of solution in the aqueous constituents of the urine, and it is very improbable that such a body should be so excreted. (*See* a paper of mine in the "*British Medical Journal*," 1863.)

I have shown that cholesterine is a very constant constituent of the large cells (*granular corpuscles*) containing oil-globules, which are abundant in the fluid of *ovarian dropsy, and sometimes in hydrocele*, and in that found in cysts generally;* in similar cells, which are common in *sputum*, and are derived from the surface of

* The bodies described as *granular corpuscles*, *inflammation globules*, *compound granular cells*, *exudation corpuscles*, and known by other names, are really composed of a number of minute oil-globules, aggregated together in the form of a spherical mass which not unfrequently becomes invested with albuminous matter, resembling a cell-wall; but I believe that usually the albuminous material is deposited with the oil-globules, and therefore that no true envelope or *cell-wall* exists.

the mucous membrane of the bronchial tubes; in the cells which are frequently very numerous about the *small arteries of the brain* in cases of *white softening*, in those found in cases of the so-called *fatty degeneration of the placenta*, and in other situations.

Cholesterine is not specially *formed* in the liver, nor can it be regarded as a special excretion separated from the blood by the liver. It is a substance of, perhaps, much less importance physiologically and pathologically than Dr. Flint and Dr. Salisbury are disposed to think. Nor is there reason to believe that the cholesterine found in the nerves is constantly being removed. It exists in largest proportion in the fatty matters of which the white substance of the nerve-fibres is composed, and there is no reason for believing that this white substance undergoes active change. It is true cholesterine aud the allied lipoid, or non-saponifiable fatty matter, serolin, are found in the blood, but only mere traces are present. It is probable that these substances result from the disintegration of some of the tissues, but there is no reason for assuming that either of them perform any very important office, or that certain important symptoms sometimes present are due alone to excess of cholesterine in the blood. I cannot admit that Dr. Flint has made out " a new excretory function of the liver," consisting of the removal of cholesterine from the blood, or that he is justified in introducing the term " *cholesteremia*," as applicable to a newly-discovered disease. Every one knows that cholesterine is one of the constant constituents of bile; but, to assert that the symptoms occurring in fatal jaundice depend upon the poisonous effects of an insoluble substance like cholesterine accumulating in the blood, is not justified by the facts. The symptoms have been explained much more satisfactorily already, without resorting to such an hypothesis. (*See* Dr. Flint's Paper—" *American Journal of the Medical Sciences*," October, 1862.)

339. **Kiestein.**—Of this peculiar substance I can give no very satisfactory account. Some years since numerous observations were made by Nauche, and repeated by Dr. Golding Bird and several other observers, with the view of ascertaining if there was any foundation for the statement that, in pregnant women, certain elements of the milk found their way into the urine, and, after the lapse of a short time (twenty-four hours to five or six days), a thin pellicle, consisting of fatty matter, a substance allied to casein, and crystals of triple

phosphate, formed upon the surface. Some went so far as to say that the presence of this pellicle was sufficient to indicate the existence of the pregnant state. This statement has, however, long since been proved to have no foundation in actual observation. In some of the cases brought forward by Dr. Golding Bird, the pellicle was absent; in others, the pellicle was observed; and the conclusion he arrived at was, that, in cases in which the pellicle was formed, it was due to the presence of certain constituents of the milk, which, from not escaping from the gland in the usual way, had been reabsorbed and separated from the blood by the kidneys.

I have not unfrequently seen a pellicle composed of animal matter, in which vibriones and fungi were abundant, and crystals of triple phosphate formed upon the surface of various specimens of urine which had been left to stand for a day or two, both from the male and from the female. Whether this is exactly the same sort of pellicle as that said to form upon the urine of pregnant women, I cannot say; but it possessed the characters usually assigned to the so-called kiestein. The animal matter has not been satisfactorily isolated, and is in many cases undergoing decomposition. In the absence of more exact information, we can attach no importance whatever to the presence or absence of this pellicle in the diagnosis of pregnancy. It may be absent in the pregnant state; and it may be present in the male, and in the unimpregnated, as well as in the impregnated female.

Other Forms in which Fatty Matter occurs in Urine.

340. Urostealith.—Dr. F. Heller reports a very remarkable case, in which small concretions, composed of fatty matter, were passed in the urine. The patient was a man, twenty-four years old, who suffered from symptoms of stone in the bladder. He passed several small solid bodies, which were found by Dr. Heller to consist of a peculiar form of fatty substance, to which he gave the name of urostealith. The man, who was treated with carbonate of potash, got quite well in a fortnight (quoted in Dr. Golding Bird's work, edited by Dr. Birkett, p. 422; Heller's "*Archiv*," 1844, s. 97, 1845, s. 1). Dr. Moore of Dublin has confirmed Heller's observations on urostealith. He examined specimens of this curious substance, which he received from Dr. Robert Adams of Dublin, and Dr. Little of Sligo

("*Dublin Quarterly Journal of Medical Science*," May, 1854, Vol. XVII., p. 473). I have had two or three specimens of solid fatty matter sent me, which were stated to have been passed in the urine, but the evidence was not conclusive. It was not certain, in one case, if they passed along the urethra at all; and, in others, it was not proved that they were not passed up in the first instance.

341. Fluid Yellow Fat and Oil Globules.—Dr. C. Mettenheimer gives two cases in which large quantities of fluid yellow fat were passed in the urine. The first was a man suffering from cancer of the lungs, who was taking a tablespoonful of cod-liver oil twice-a-day. The second was that of a woman who was recovering from acute inflammation of the kidneys, and was taking a mixture composed of henbane and hemp. ("*Archiv. des Vereins*," B. 1, Heft. 3.)

Dr. Henderson, of Clifton ("*Brit. Med. Journ.*," May 22nd, 1858), reports three cases, in which fatty matter in the form of fine oil-globules was suspended through the urine. The patients suffered from heart affection. The oil-globules were only seen on one or two occasions. The nature of the fatty matter could not be ascertained. From six drachms of the urine, of one case, Dr. Herapath obtained ·015 grains of an oily fatty matter. Dr. Herapath refers to a case in which "a large dose of castor-oil was gradually, almost wholly, eliminated by the kidneys, during several days after administration." Dr. Henderson believed that the bottles in which the urine he examined, was collected, were perfectly clean, and he considers that perhaps the fatty matter was derived from the chyle, although no albumen was detected, which, however, would have been the case, if this supposition were correct. Dr. Henderson kindly sent me a little of the ethereal solution of the fat obtained from one of his cases; but the amount was too small for chemical examination.

342. Fatty Matter in Rabbits' Urine.—Dr. Siegmund found a quantity of fatty matter in the urine of rabbits to which cubebs had been given. The excretion of fatty matter continued as long as the cubebs were administered. After death, no morbid change was discovered. It disappeared when the cubebs were omitted, but reappeared when they were administered again. The same observer also found that, although cantharides and cubebs irritated the kidney, they did not diminish the proportion of urea excreted.

343. Erroneous Observations connected with the Presence of Fatty Matter in Urine.—Numerous other instances, in which fat has been said to have been passed in considerable quantity, are on record; but there can be little doubt that, in many of these cases, the chemical characters of the substance supposed to be fatty were not carefully ascertained. There is reason to believe that the iridescent pellicle, which really consists principally of fungi, vibriones, and crystals of triple phosphate, from its general resemblance to a thin film of oily matter, has been mistaken for fat. Small portions of oily matter not uncommonly become mixed with the urine accidentally, and now and then the urine is put into an oily bottle and sent for examination. Even a single drop of oil, shaken up with three or four ounces of urine, becomes divided into a great number of minute oil-globules, and upon microscopical examination there appears to be a much larger quantity of fatty matter present than is really the case. Many practitioners have been deceived in consequence of the admixture of milk with urine. This is not an uncommon practice, and we should be very careful not to be misled by impositions of this kind. It is hardly credible what trouble some patients will take to deceive us; and very often deception is practised and carried on for a long time without detection. From not being able to discover any reasonable motive, we are sometimes too ready to conclude that our suspicions are unfounded; and thus we may be led to believe statements which are really false, and report cases apparently of a very exceptional character, which only prove that great ingenuity has been employed for the mere purpose of imposing upon us.*

* I am much interested in the question of the removal of fatty matter by the kidneys; and I shall be very much obliged to any one who will send me specimens of urine containing fatty matters in any unusual form, or reports of well authenticated cases.

CHAPTER XIV.

URINE IN DISEASE. II. OF LIGHT AND FLOCCULENT DEPOSITS. *Mucus—Altered Pus resembling Mucus—Of the Clinical Importance of Mucus—Incontinence of Urine not dependent upon Organic Disease—On the Treatment of Irritable Bladder and Incontinence of Urine—Vibriones—Torulæ, including the Sugar Fungus and Penicillium Glaucum—Sarcinæ—Trichomonas Vaginæ—Epithelium of Kidney, Ureter, Bladder, and Urethra—Vaginal Epithelium—Casts of the Uterus and Vagina—Leucorrhœa—Of the Treatment of Leucorrhœa—Spermatozoa—Medico-legal Investigation—Vegetable Bodies resembling Spermatozoa—Casts of the Renal Tubes—*A. *Casts of Medium Diameter, about the one-seven-hundredth of an inch—Epithelial Casts—Casts containing Dumb Bells—Granular Epithelial Casts—Casts containing Oil—Fat-Cells—Casts containing Blood—Casts containing Pus.* B. *Casts of Considerable Diameter, about the one-five-hundredth of an inch—Large Waxy Casts.* C. *Casts of Small Diameter, about the one thousandth of an inch—Small Waxy Casts—Of Casts in a Clinical point of view.*

OF URINARY DEPOSITS.

It will be convenient, for the purposes of description, to arrange these insoluble substances in a certain order; and I think that the subdivision I have adopted will be found of some assistance to the memory, and will help the observer to discover quickly the nature of different insoluble substances. I do not make an attempt to devise a natural classification, but merely propose to arrange deposits in the

order in which they can be practically treated of most conveniently. There are objections to this, as to every other sub-division; but, as it is simple, and depends merely upon the general characters which can be observed by the unaided eye, I think it will be found practically useful.

Insoluble substances may *float on the surface of the urine*, or may be *diffused throughout the fluid*, or they may *sink to the bottom*, forming *deposits* of greater or less density.

1. *Insoluble Matter floating upon the Surface of Urine, or diffused through the Fluid.* Fatty matter in a very minute state of division, as it occurs in cases of *chylous urine*, is one of the most important substances contained under this head, and has been already considered.

Urate of Soda is another substance which is often suspended in a molecular state through the fluid, rendering it turbid; but this also forms a deposit, and it will therefore be more convenient to consider it under that head. Phosphates are found not unfrequently in the pellicle upon the surface of urine; but in this case they are merely buoyed up, as it were. This substance will be described under *urinary deposits.*

2. *Light and flocculent Deposits, usually transparent, and occupying considerable volume.* Under this head I shall include mucus, with different forms of epithelium derived from the kidney, ureter, bladder, urethra, vagina, &c.,; certain well-defined forms of fungi and vibriones; sarcinæ; spermatozoa; casts of the uriniferous tubes; rarely, benzoic acid in small quantity (*See* note on page 165).

3. *Dense and opaque Deposits, occupying considerable bulk.* This class includes only deposits of urates, pus, and phosphates.

4. *Granular or crystalline Deposits,* occupying a small bulk, sinking to the bottom, or deposited upon the sides of the vessel. This division includes a great many different substances. Among the most important are uric acid, oxalate of lime, certain forms of triple phosphate and phosphate of lime, cystine, carbonate of lime, blood-corpuscles, and very rarely, cancer-cells, tubercle-corpuscles, and small spherical cells.

I proceed now to the consideration of the different substances comprised in the first class of urinary deposits. Many of these occupy a considerable bulk, although the actual quantity of matter entering into the formation of the deposit is exceedingly small. If

dried, one of the most bulky of these deposits, separated from six or eight ounces of urine, would hardly weigh half a grain. The mode of separating urinary deposits from the urine, of examining and preserving them, is described in Chapter III., § 52, *et seq.*

II.—First Class of Urinary Deposits.

344. Mucus.—If healthy urine be allowed to stand for a few hours after it has been passed, a bulky, flocculent, and very transparent cloud will be deposited towards the lower part of the vessel. Upon examining this in the microscope, a few delicately granular cells, rather larger than a blood-corpuscle may be seen, scattered sparingly through a transparent substance, in which only a few minute granular points can be detected. A few cells of epithelium from the bladder, or from some other part of the urinary mucous membrane, are not unfrequently met with. Nothing more is observed in the mucus found in *healthy* urine. In disease, however, this mucus increases in quantity, and forms a more or less transparent deposit, containing numerous ill defined cells, similar to those above referred too, with much epithelium, the character of which depends upon the particular part of the mucous membrane from which it has been derived (§§ 353, 354). The characters of ordinary vesical mucus are represented in Fig. 85, Plate XVII. The larger cell to the left of the figure is a cell of bladder epithelium.

Little collections of mucus, with imperfectly formed cells, are not unfrequently seen in urine. These are generally derived from the follicles of the urethra, or from the prostate. Long shreds of mucus-like material are sometimes formed in the kidneys and in the seminal tubules, and escape with the urine. (Plate XVII., Figs. 83, 84; "*Illustrations,*" Plate XIII., Fig. 2.)

345. Altered Pus, resembling Mucus.—The very thick glairy deposit, which is frequently found in the urine in cases of disease of the bladder, is often termed '*mucus,*' but its real nature is very different. It consists, in fact, of *pus* altered by the action of *carbonate of ammonia* which has been set free in consequence of the decomposition of the urea caused by some animal matter acting as a ferment after the urine has left the bladder. In some cases, this change even commences in the bladder itself; and the expulsion of

the glairy viscid matter often gives rise to serious inconvenience. When an attempt is made to draw off the urine with a catheter, the instrument sometimes becomes completely plugged up. Urine of this kind exhibits a highly alkaline reaction, evolves an ammoniacal odour, and frequently contains a considerable deposit of crystals of the triple or ammoniaco-magnesian phosphate, with granules of phosphate of lime. Liquor ammoniæ and potash exert an action upon pus similar to that of carbonate of ammonia.

I have observed, in several cases, that when pus comes from an abscess in the kidney, or from the pelvis of the kidney, it is not accompanied with crystals of triple phosphate. On the other hand, when it is derived from the bladder, crystals of these earthy salts are almost invariably present. This point should be taken into consideration before arriving at a diagnosis in doubtful cases.

It should be borne in mind that, if basic phosphate of soda be added to urine, ammonia is always set free in considerable quantity. Dr. G. O. Rees suggests that the ammonia is often set free in this manner, and not by the decomposition of the urea. The same observer (Lettsomian Lectures, "*Medical Gazette*," 1851) considers that the alkalinity of the urine is dependent in certain cases upon the secretion of a large quantity of an alkaline fluid from the mucus membrane of the bladder. When the mucus membrane is exposed, it is always found to be moistened by an alkaline fluid. When irritated, a quantity of this alkaline fluid, supposed to be more than sufficient to neutralise the acidity of the urine, is poured out. Dr. Rees explains the fact, that the acid reaction of urine not unfrequently becomes more intense after giving alkalies, by supposing that the alkali allays the irritable state of the mucous membrane, which, in consequence, secretes less of the alkaline fluid. In injuries to the spine, the beneficial action of alkalies is explained by supposing that the mucous membrane requires a greater quantity of alkali to protect it than in health. Still it is difficult to associate this explanation with the fact that healthy urine is *always* acid. If a slight increase of this *natural* acid really endangered the integrity of the mucous membrane, by exciting the secretion of excess of a *destructive* alkaline substance, one is almost forced to the false conclusion that the actual condition which exists is not so advantageous to the individual as the existence of a mucous membrane adapted to bear without change the constant action of an acid fluid

would be. Moreover, in a vast number of cases, urine, containing a very considerable excess of acid, does not produce the result just alluded to.

The mucus which is deposited from many specimens of urine often contains a great number of octohedral crystals of oxalate of lime, frequently so very minute as to appear, under a power of two hundred diameters, like a number of dark but square-shaped spots. Their crystalline form may be demonstrated by the use of a very high power; but they may be recognised with certainty with a little practice, as their square shape presents a characteristic appearance, with which the eye soon becomes familiar. They are insoluble in a solution of potash, and also in strong acetic acid. These crystals are commonly not deposited until after the urine has left the bladder; and if it be allowed to stand for a longer period, they frequently undergo a great increase in size. It is probable that the mucus excites change in the urates, causing their decomposition, and the formation of oxalate of lime. Fragments of hair, small portions of cotton fibre, and other substances of accidental presence, are not unfrequently encrusted with them.

346. Of the Clinical Importance of Mucus.—Although, as already stated, the great majority of cases in which the urine is said to contain large quantities of mucus, are really examples of pus in the urine, which has been rendered glairy and transparent by the action of ammonia, true mucus is sometimes found in the form of long transparent shreds, which are scarcely visible unless the field of the microscope be illuminated very slightly. Rich transparent mucus shreds may be derived from several parts of the urinary surface; they may come from the follicles of the urethra or prostate, from the vesiculæ seminales, from the vas deferens, or from the seminal tubules. I have seen the most distinct branching cylindrical masses of mucus from the *uriniferous tubes* in many instances (*see* Plate XVII., Figs. 83, 84). These cases do not appear to have been noticed previously. The character of these "mucus casts" is discussed in page 61. Their formation is sometimes associated with an irritable state of the urinary organs generally, and, in very many cases of irritable bladder, evidently not depending upon organic disease, small quantities of mucus, in the form of cylinders, may be detected in the urine.

This mucus is very soon destroyed by maceration in fluid, and, unless the urine be examined very soon after it has been passed, the distinctive character of such mucus-casts will have disappeared. If urates be present in the urine they will be deposited in and upon the mucus, in which case the mucus-casts form very prominent objects. Minute crystals of oxalate of lime are also frequently deposited upon these casts. There is no difficulty in distinguishing these bodies from the true casts, wrongly termed "fibrinous;" for, although composed of a firm elastic material, casts do not consist of fibrin (*see* § 105).

347. Incontinence of Urine not dependent upon Organic Disease.—In irritable conditions of the bladder and urinary organs generally, there is sometimes an increased secretion of mucus, but this is not constantly the case; and all practitioners are familiar with cases of incontinence of urine, not dependent upon any organic disease whatever, in which the urine does not contain the slightest deposit of any kind. Some of these cases are very obstinate. The condition is frequently met with, but perhaps more commonly, in young and old people than in persons about the middle periods of life.

As is well known, incontinence of urine is very common in young children, and may depend upon almost any peripheral irritation, such as dentition, intestinal worms, enlarged glands, &c., but very often it is connected with a naturally excitable state of nervous system. Commonly enough, it occurs only during the night, and sometimes the child acquires a *habit* of thus voiding the urine, unless care is taken by the nurse to take him up regularly after certain intervals of time (three or four hours), so as to prevent much urine from accumulating in the bladder. In many cases the urine is a little too acid, when a few doses of bicarbonate of potash and attention to diet will relieve the troublesome affection.

In old age the bladder often becomes very irritable, although there is no morbid change whatever in its structure, and a patient is unable to retain his water for more than half-an-hour or an hour at a time. Any disturbance of the digestive organs will sometimes produce increased distress. The urine is perhaps too acid or too highly concentrated. Patients who suffer thus, by concentrating their attention too much upon their ailment, often make matters worse.

Incontinence of urine may, of course, be produced by a great variety of conditions. Its occurrence in inflammation of the bladder, cancer, and some other conditions, will be referred to in the proper place.

348. On the Treatment of Irritable Bladder and Incontinence of Urine, not dependent upon Organic Disease.—This affection will require different treatment according to the age at which it occurs. The irritable bladder of children generally depends upon peripheral nervous irritation, and is often relieved by gentle purgatives, and small doses of alkalies. When arising from teething or from worms, the treatment is obvious. In young children, incontinence occurring during the night need cause no alarm whatever, as it generally passes off as the child grows older.

This troublesome symptom occurs in young persons of both sexes, and is occasionally very obstinate. Not unfrequently it seems to be due to the habit of sleeping on the back, when a blister applied to the buttocks will generally cure the malady by compelling change of position. I have seen it in youths of scrofulous habit whose strength has suffered from growing too fast. Such cases are almost certainly cured by a generous diet, the tincture of sesquichloride of iron, quinine, and cod liver oil, but it is often necessary to keep the patient under this plan of treatment for two or three months.

Nervous old men often suffer a good deal of inconvenience from irritable bladder not dependent upon organic disease. If they take a little more wine than they ought, or live on a richer diet than usual, or become a little more irritable in temper, they will be called up several times in the night. The state of urine causing this annoyance is generally dependent upon the stomach being a little out of order, and a few doses of bicarbonate of potash after meals, a mild sedative and a gentle purge, generally relieves the annoyance. Sometimes a small dose of blue pill or calomel affords great relief. If obstinate, it is well to try the effect of an opium or henbane suppository.

349. Vibriones.—After urine, containing a little epithelium or other animal matter, has been allowed to stand for some time, numerous elongated bodies, varying much in length and possessing

active movements, are developed in it. These little bodies appear as simple lines under a magnifying power of two hundred diameters; but, by careful focussing, under one of five hundred or six hundred diameters, the longest of them are seen to consist of filaments with numerous transverse lines, indicating a similarity of structure with some of the lower vegetables. They sometimes very closely resemble the algæ ordinarily found in the mouth. Most observers agree as to the vegetable nature of the bodies in question; but Dr. Hassall has recently arrived at the conclusion that they are animal, and that the movements are voluntary ("*Lancet*," Nov. 19th, 1859). That the movements are not merely molecular, is quite certain; but, to apply the term "voluntary" to such movements as these, seems to me quite unjustifiable. There is not the slightest evidence in favour of such a conclusion. As investigation proceeds, the conclusion that many forms, which were considered animal, are really of a vegetable nature, is more frequently forced upon us than that organisms, hitherto held to be vegetable, must really be regarded as animal. The time has, however, gone by, when attempts were made to draw an arbitrary line between the lowest classes of the animal and vegetable kingdom.

These vegetable organisms are seen as minute lines under the microscope, and they undergo very active movements, the longer ones twisting about in a serpentine manner. They are sometimes developed in urine before it has left the bladder, and always occur in decomposing urine. (*See* Plate XV., Fig. 73 at *b*.)

Other living organisms are frequently met with in urine. Numerous forms of animalcules, one of which Dr. Hassall includes in the genus *bodo* (*bodo urinarius*), are also observed in various specimens. It is probable that many of these different forms merely indicate different stages of existence of one species.

350. Torulæ, including the Sugar-Fungus and Penicilium Glaucum.—Certain forms of vegetable fungi or torulæ are developed in urine after it has been standing for some time. The period which elapses before the appearance of the fungi, and the particular species which is developed, vary much in different specimens of urine, and in different cases of disease. In diabetes, torulæ are sometimes developed in considerable number within twenty-four hours after the urine has been passed; and their growth at this early period leads

the observer to suspect the presence of sugar, which must be confirmed by the application of chemical tests (§§ 276, 277). Different forms of fungi are represented in Plate XV., Figs. 73, 74, 75. (*See* also "*Illustrations*," Plate XIX, Figs. 1 to 7; Plate XXI., Fig. 6; Plate XXIII., Figs. 2, 3, 4, 5.)

Sugar Fungus. Dr. Hassall has communicated a paper upon the development of torulæ in the urine, to the Royal Medical and Chirurgical Society, which will be found in the volume of "*Transactions*" for 1853, in which he arrives at the conclusion that there is a species of fungus which is developed in specimens of urine, containing even very minute traces of sugar, which may be looked upon as characteristic of the presence of this substance, as it occurs in no other condition of the urine. This is the *sugar fungus.* But neither the characters nor the occurrence of the fungus are sufficiently constant to enable us to conclude positively as to the presence or absence of sugar in the urine. The sugar fungus which grows in diabetic urine is identical with the yeast plant. (*See* Fig. 66*, Plate XIII., after Hassall.)

Penicilium Glaucum. Besides the sugar fungus, there is another species which is very commonly met with in acid urine containing albumen, if exposed to the air. This is the *Penicilium glaucum*, the same fungus which is developed in the lactic acid fermentation (Plate XV., Figs. 73, 74, 75?). This species is also represented in the "*Illustrations*," Plate XIX., Figs. 1, 4, 5.

The microscopical characters of the fungi in different specimens of urine vary considerably; but these differences depend not so much upon the existence of several distinct species of plants, as upon the stage of development which the fungus has reached. Thus, as Dr. Hassall has stated, in some specimens, the growth of the fungus is arrested at the sporule stage; in another, not until a thallus is formed; and in a third, it goes on until aerial fructification takes place, and new spores are developed. But it is only in the last condition that constant distinctive characters can be demonstrated. The degree of acidity of the urine, and the length of time during which it has been exposed to the air, appear to determine, in great measure, the stage of development which the fungus attains. Dutrochet long ago stated that an acid reaction and albumen are necessary for the development of penicilium; but Dr. Hassall, in some more extended experiments, proved that the fungus often

appeared in acid urine which contained no albumen; and I have frequently observed the same point myself.

The penicilium glaucum, as well as the sugar fungus, may be met with in saccharine urine, because all the necessary conditions for its development may be present, namely, exposure to air, an acid liquid, and a certain quantity of nitrogenous matter. Mr. Hoffman, of Margate, showed that the spores of penicilium would, under favourable circumstances, give rise to the development of the sugar fungus.

As Dr. Hassall was, I believe, the first to prove, the fructification of these two fungi is totally distinct, and in this stage of growth, no one could fail to distinguish one from the other. But I am sure no microscopist could distinguish these fungi during the *sporule stage*, and although the thallus of well developed penicilium differs from that of well developed sugar fungus, I have seen thalli of these fungi which resemble each other in thickness, mode of branching, and in very minute characters. So that, although in their perfect condition the two fungi exhibit distinctive characters, it is only in this stage that we can demonstrate them to be distinct species.

Dr. Hassall, in his recent work on the urine, represents the sporules of the sugar fungus as being very much larger than those of penicilium glaucum. I have seen many specimens in which the sporules were the same size, and it is easy to obtain sporules of the sugar fungus much *smaller* than those of penicilium.

From a careful consideration of this question, then, I think we may conclude that although well defined differences may be made out in the perfect state of development of these fungi, *Penicilium glaucum* and *Torula cerevisiæ*, it must be conceded that there are also forms at certain stages of growth which could not be distinguished from one another. The large circular sporules of the sugar fungus are distinct enough from those of penicilium glaucum; but oval and circular sporules, which cannot easily be distinguished, are to be obtained under certain circumstances from each plant.

351. Sarcinæ are little vegetable organisms in the form of little cubes, which are from time to time met with, in the matter rejected, in peculiar cases of obstinate vomiting. They have been observed, however, in other fluids, and occasionally occur in the urine; but the sarcinæ which I have seen in the urine were smaller than those which are usually observed in vomit.

Sarcinæ have been met with in the urine by Heller, Dr. Mackay, Dr. Johnson, and by myself, under circumstances which leave no doubt that this vegetable organism is sometimes developed in urine. I once analysed a specimen of urine containing sarcinæ, which was sent me by my friend Dr. Brown, of Lichfield. It was acid; specific gravity, 1018·6.

Analysis 65.

Water	952·8
Solid Matter	47·2
Organic Matter	37·9
Fixed Salts	9·3

The specimen was carefully examined for lactic acid, but not a trace could be detected. Sarcinæ in vomit are represented in Plate XXII., Fig. 118.

352. Trichomonas Vaginæ.—Donné some years ago described, under the name of *Trichomonas vaginæ*, an organism which he considered to be of an animal nature. It consists of a rounded cell, with vibratile filaments projecting from it, and was found in the urine of females suffering from leucorrhœa. Kölliker and Scanzoni have confirmed Donné's observations, and have detected the *trichomonas* in the vaginal mucus both of impregnated and of unimpregnated women. I have never been fortunate enough to meet with a specimen of this organism.

353. Epithelium of Kidney, Bladder, and Urethra.—The epithelium from the kidney has been already described. It is figured in Plate IX., Fig. 44; and in the "*Illustrations,*" Plate XXIV., Figs. 1, 2, 3, 4. The cells from the *ureter* are of the columnar form, and some are spindle-shaped. (Plate IX., Fig. 46; also "*Illustrations,*" Plate XXIV., Fig. 5.) In form, and indeed in their general appearance, these cells much resemble those found in some scirrhus tumors. Care must be taken not to make the mistake in cases of suspected cancer of the kidney.

The epithelium of the *bladder* varies much in different parts of the organ. In the fundus, there is much columnar epithelium mixed with large oval cells; whereas, in that part termed the trigone, large and slightly flattened cells, with a very distinct nucleus and nucleolus, are most abundant. Columnar epithelium appears to

line the mucous follicles, while the scaly lies on the surface of the mucous membrane between them. Many of the large oval cells of bladder-epithelium lie upon the summit of columnar cells, and their under surface exhibits corresponding depressions. Various forms of bladder-epithelium are represented in Plate XV., Fig. 76; Plate XIX., Fig. 100; and in Plate XXII., Fig. 120; the manner in which the young cells of vesical epithelium multiply, is represented under a power of 700 diameters. The young cells are composed of a perfectly soft granular material, and like other young cells possess no limitary membrane or cell-wall whatever. These large cells of bladder epithelium grow very fast in cases of epithelial cancer, affecting this organ. (*See* § 421.)

The epithelial cells of the *urethra* are, for the most part, of the columnar form; but mixed with this there is also a good deal of scaly epithelium. Towards the orifice, the epithelium is almost entirely of the scaly variety. The epithelium of the *glans* is of the scaly variety, and mixed with it is a quantity of soft white matter, seen under the microscope to consist of granules and numerous globules of fat, rich in cholesterine, with granules and globules of earthy phosphate. This is the secretion from the modified sebaceous glands in the mucous membrane of the corona, the so-called *Smegma Preputii*, which accumulates in some cases to an enormous extent. In a specimen, which was removed by operation by my friend Mr. Bird, now of Melbourne, I found epithelial cells with many well formed crystals of cholesterine. Upon analysis, the following constituents were detected and estimated in ten grains.

Analysis 66.

Water	7·46
Solid Matter	2·54
Extractives soluble in alcohol and cholesterine	·24
Epithelium, &c.	2·02
Fixed Salts	·28

354. Vaginal Epithelium.—The large cells of scaly epithelium, so commonly met with in the urine of females, and derived from the *vagina*, are represented in Plate XV., Figs. 77, 78. They vary, however, much in size and form, and are sometimes very irregular in shape, with uneven ragged edges.

Fig. 72.

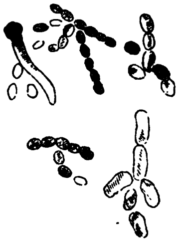
§ § 327, 330

Fig. 73.

× 215

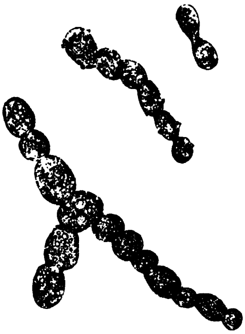
§ § 350, 351

Fig. 74.



§ 350

Fig. 75.



§ 350

Fig. 76.

× 215

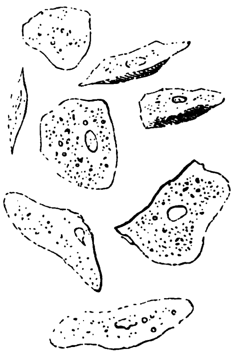
§ 353

Fig. 77.

× 215

§ 354

Fig. 78.



§ 354

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355. Casts of the Uterus and Vagina.—A considerable thickness of the epithelial layer of the vagina, and according to some observers also that of the uterus, is sometimes shed in the form of a membranous cast or mould. I have seen such epithelial casts or moulds from the rectum, æsophagus, and from the stomach. They correspond to the layers of cuticle which are detached from different parts of the cutaneous surface after scarlatina.

Dr. Arthur Farre has recorded some interesting cases of "exfoliation of the epithelial coat of the vagina," in Vol. I. of my "*Archives.*" The appearance of the specimens is represented in Plate XII. of the "*Archives of Medicine.*" Dr. Farre remarks that the act of exfoliation is repeated at intervals. The casts described by Dr. Farre are interesting in another point of view, as showing the real form of the vagina when in its ordinary empty and collapsed condition. (*See* "*Archives,*" Vol. I., p. 71.) Dr. Tilt has also described some interesting cases of the same kind. His opinion is, that some of these casts come from the uterus, while others are formed, as Dr. Farre stated, in the vagina. The beautiful specimen figured in Plate XVI., Fig. 79, is one of those examined by Dr. Tilt and considered by him to come from the uterus, although the character of the epithelium of which it was composed, agree more closely with those of the vaginal cells. (*See* "*Archives,*" Vol. III., p. 26.)

356. Leucorrhœa.—In this condition very many imperfect cells of vaginal epithelium are formed upon the surface of the mucous membrane, as well as pus-corpuscles. Many pus-corpuscles originate in the cells of vaginal epithelium, even after the epithelial cells have assumed their distinctive form, but many of the younger cells of vaginal epithelium, and those in the follicles of the mucous membrane, divide and subdivide, giving rise at length to multitudes of the spherical granular cells we know as "pus-corpuscles," which divide and subdivide very rapidly if freely supplied with nutrient matter. For the manner in which pus is formed from the germinal matter of vaginal epithelium, *see* Plate XIX., Fig. 98; and for the mode of multiplication of the pus-corpuscles, Plate XIX., Figs. 97, 99.

357. Of the Treatment of Leucorrhœa.—Although it is not the province of this work to discuss the nature and treatment of leucorrhœa, it may be well to state, that many cases seem to depend

upon an impoverished state of blood, and get quite well, if attention be paid to the general health. Of all remedies the tincture of sesquichloride of iron is one of the most useful, and when there is any irritability of the mucous membrane, tincture of henbane, opium, or hop, or the extract of indian hemp, will be found useful. The local application of Goulard water with sedatives, and the injection of cold or tepid water, and the beneficial effects of the cold or tepid hip-bath, in this condition, are so well known to practitioners, that it is almost needless to refer to them.

358. Spermatozoa.—The urine should be examined for spermatozoa, soon after it has been passed, as they may undergo change. In some specimens of acid urine, in which vibriones are not developed, the spermatozoa may be preserved for days without destruction. They may be distinguished with a power of about two hundred diameters; but, unless the eye is familiar with them, it is better to employ one of from four hundred to five hundred. In one case, I met with spermatozoa covered with granules of urate of soda, which rendered the forms very distinct.

Spermatozoa often form, with the mucus from the seminal tubules, whitish flocculi, which are suspended in the urine. They may, however, sink to the bottom, forming a deposit invisible to the unaided eye. Spermatozoa are represented in Plate XVI., Figs. 80, 81.

359. Mucus Casts from the Seminal Tubules are sometimes found in the urine. Some are very roughly represented in Plate XIII., Fig. 2, of the "*Illustrations.*" Occasionally spermatozoa are packed together in great number, so as to form, with the mucus in which they are embedded, casts of considerable dimensions. A very good specimen is represented in Plate XVI., Fig. 80, from the urine of an old man of 80.

360. Of the Clinical Importance of Spermatozoa in Urine.—Spermatozoa are not uncommonly found in the urine in health. It is only when their appearance is constant, and accompanied with other more important symptoms, that the practitioner is justified in interfering. I would earnestly draw attention to the importance of exercising the greatest caution in these cases; for the mere allusion to the presence of spermatozoa may do more harm to a nervous

Fig. 79.

§ 355

Fig. 80.

× 215

§ 359

Fig. 81.

§ 358

Fig. 82.

× 403

§ 362

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patient than can be counterbalanced by the good produced by medical treatment. The occasional presence of spermatozoa in urine must not be looked upon, in itself, as evidence of that condition to which the name of "*spermatorrhœa*" has been applied—a term which I am sorry to employ at all, and which, I think, ought to be abolished altogether. There is, in fact, no *disease* to which the term "spermatorrhœa" can be correctly applied. Spermatozoa are commonly found in the urine. The secretion of the testicle, like that of other glands, must, from time to time, escape. Spermatozoa are frequently seen in the urine of young men in perfect health, and I have seen considerable numbers in the urine of a hale old man above 80 years of age. This was a decided case of "spermatorrhœa;" and there is no doubt, that if this old gentleman's urine had been examined by some of the quacks who pretend to make this "disease" a special study, he would have been favoured with a list of the frightful consequences of this dire condition, and perhaps subjected to the appropriate remedies for preventing cerebral congestion, phthisis, epilepsy, general paralysis, insanity, and the other horrors which are stated by some persons to result from the involuntary escape of the secretion of the testicle.*

* In a former edition of this Work, and also in "*The Microscope in its Application to Practical Medicine*," I have expressed in plain terms my own opinion upon the use of this detestable word, and I have found no reason to alter my view; but as several pages of some works recently published are devoted to the consideration of "spermatorrhœa and impotence," it is necessary for me to state more fully why I have expressed myself in a manner which, to some, may perhaps have appeared hasty and unsupported by evidence.

One author has complained that some of our Hospital Physicians have fallen into the '*error*' of making too light of this affection, and one or two in particular have even gone the length of ignoring its existence altogether. It is only right that I should admit that I fall under this 'stigma' (?), and it is but due to those who differ from me that I should give reasons for the opinion which, in common, I believe, with very many medical practitioners, I have long held upon this matter. The position I have taken up is simply this—that there is *no such disease* as "spermatorrhœa," as usually defined.

It has been truly stated, that charlatans, for their own selfish purposes, too often work upon the fears of their patients, and exaggerate the evil consequences to be anticipated; but what encouragement does the practitioner afford, who, under the head of consequences of spermatorrhœa, includes "*phthisis, cerebral congestion, epilepsy, general paralysis and insanity—lastly, enfeebled sexual power, and ultimately impotence*"! (Hassall)

These have been stated to be consequences of "spermatorrhœa," but we are not informed whether '*possible*' or '*probable*.' Spermatorrhœa has been defined to be "all losses of seminal fluid not occurring as the result of sexual intercourse." As the heading "SPERMATORRHŒA AND IMPOTENCE" has been adopted, we are clearly justified in concluding that impotence, to say the least, is regarded by some as not an uncommon consequence of "spermatorrhœa." I have seen many cases which have been called "spermatorrhœa," but I never saw one which ended in any of the above terrible consequences. That impotence does occur I do not deny, but lasting impotence, not depending upon some congenital defect, or some obvious structural morbid change, is a most uncommon affection; indeed, I have myself never met with a single case.

I have been unable to arrive at any other conclusion than this—that *spermatorrhœa, as defined, is not a disease at all*. All practitioners are well acquainted with the real nature of the cases included under this head. It seems to me neither necessary

361. Medico-Legal Investigation.—We are sometimes called upon to examine stains upon linen, or the vaginal mucus, in cases of suspected rape. Such an investigation must be undertaken with the greatest care, and a positive opinion must not be expressed if the observer have the slightest doubt as to the nature of the bodies in question; neither should a positive conclusion be drawn from the presence of only *one* structure like a spermatozoon, nor from ***supposed fragments*** of their bodies. Fragments of cotton or linen sometimes assume forms very like those of spermatozoa. The mucus which has been dried on the linen, even after it has been kept for some time, in which they are suspected to be present, may be remoistened with distilled water, without the spermatozoa being destroyed. For cases in which spermatozoa were detected, *see* "*Archives of Medicine,*" Vol. I., pp. 48, 139; "*Illustrations,*" Plate XXI., Fig. 2.

362. Vegetable Bodies resembling Spermatozoa.—The only structure occurring in urine, or of renal origin, at all liable to be mistaken for spermatozoa, as far as I am aware, is a form of vegetable growth which I have only once met with, in a specimen of urine kindly sent to me by my friend Mr. Masters, of Peckham

nor decent to allude to all that has been said upon the subject, or to recount the cruel and often useless and unnecessary means that have been proposed and adopted for the treatment of losses of seminal fluid.

It cannot be too widely known that the importance attached to this so-called disease is not justified by observation—that those who pretend to have made a special study of the disease, and to have discovered means of cure unknown to the profession, are mere pretenders—and that every practitioner is well acquainted with the condition, and fully conversant with the treatment that should be adopted.

It is useless to refer to the injuries inflicted by charlatans physically, morally, and commercially, because it appears that the law at present affords no remedy. It is a disgrace that disgusting hand-bills, headed "Spermatorrhœa," should be thrust into the hands of passers by, in all parts of the town; and that most immoral exhibitions, under the title of "Museums," should be permitted to flourish in a city like this; and it is a shame that it should be possible in law for an impostor to mulct a poor, foolish, labouring man of £5 and £10 for a dozen bottles of something closely allied to mucilage in composition, for the relief of an imaginary ailment. Yet so it is, and without doubt will continue. Charlatans, in all departments, well know that obstinacy, indolence, and wilful ignorance, form a part of the character of all dupes, and that in all classes of civilized society there are always persons with these mental characteristics in sufficient number to afford them a favourable reception, to court and patronize them, and to load them with flattery and liberal and material support. Quacks well know that when their true character is found out, those deceived by them will feel so much ashamed of themselves that they have nothing to fear from exposure; and the utmost inconvenience that can ensue to them will only necessitate a change in the seat of operations.

It is obvious that the public prosecution of a most extortionate rogue involves the public confession of unutterable folly on the part of the dupe; and although nothing is more common than for people to be imposed upon, it is rare indeed for an individual to confess that he himself was one of the foolish persons who could not see through a very transparent trick.

The diffusion of that which is true can alone enable people to detect what is false, and to protect themselves successfully from the imposition of pretenders—medical, social, and scientific.

Rye. Mr. C. Roberts, of St. George's Hospital, has taken very careful notes of the case. Some of the bodies in question very closely resembled spermatozoa; but their true nature was ascertained by noticing the character of many other specimens of the vegetable growth (Plate XVI., Fig. 82). An account of this case is given in the "*Archives of Medicine*," Vol. I., p. 251.

Casts of the Uriniferous Tubes.

363. Casts of the Renal Tubes are seldom found unmixed with other deposits. Frequently they are accompanied with much epithelium, and in many cases blood-globules are present in considerable number. Occasionally, however, we meet with a transparent and scarcely visible deposit, consisting entirely of casts. The connexion between different renal diseases and the presence of casts in the urine has been demonstrated most conclusively by Dr. Johnson; many who have not patiently studied the matter, have confidently asserted that the characters of casts are not of that importance in diagnosis which other observers have maintained. Some, also, even go so far as to say that the different morbid states of the kidney, familiar to everyone, are but different stages of one and the same disease. It is much to be regretted that observation should be retarded by hasty and confident assertions of this kind. All that is to be said is simply that a few months careful study in the wards of a hospital and in the dead-house, will serve to convince any unprejudiced observer that the nature of renal disease may be diagnosed in many cases, by the microscopical characters of the urinary deposit, and that there are several essentially distinct forms of renal disease. I can, from my own observations, testify strongly to the truth of the general conclusions arrived at by my colleague, Dr. Johnson, upon these questions.

Of casts there are several different forms, which are to some extent characteristic of the morbid changes taking place in the structure of the kidney. As has been shown, the cast varies in diameter with that of the canal of the uriniferous tube; but probably, after its formation, it contracts slightly, and in consequence it readily passes from the tube, and escapes into the urine. If the epithelial layer on the basement membrane of the tube be of

its ordinary thickness, we shall have a cast of medium size. If the cells be enlarged, and adhere firmly to the basement membrane, the cast will be fine and narrow; while, on the other hand, if the tubes be entirely stripped of epithelium, the basement membrane alone remaining, the diameter of the cast will be considerable. In describing the different varieties of casts it will be convenient to divide them into three classes, according to their diameter.

Numerous figures of the various forms of casts are given in the "*Illustrations of the Urine, Urinary Deposits, and Calculi,*" Plates XIV., XV., XVI., XVII., and XVIII. These figures have been traced, from the objects under examination, upon the stone from which the plates have been printed. In Plates XVII., XVIII., of the present work, and in Plate X., Figs. 50, 51, 52, some variety of casts are represented.

Casts may be divided into different classes according to their diameter. The first class of casts, which is by far the largest, will include casts of medium size; the second, those of considerable diameter; and the third will comprehend the smallest casts that are met with.

A. Casts of medium Diameter, about the 1-700th of an inch.

1. Epithelial casts.
2. Pale and slightly granular casts, with or without a little epithelium, or epithelial *débris*.
3. Granular casts, consisting entirely of disintegrated epithelium.
4. Casts containing pus or blood.
5. Casts containing oil.

B. Casts the Diameter of which is about the 1-500th of an inch.

1. Large transparent "waxy casts."
2. Large and darkly granular casts.

C. Casts the Diameter of which is about the 1-1000th of an inch.

Small waxy casts.

A.—Casts of Medium Diameter.

364. Epithelial Casts are met with in great number in all cases of *acute nephritis;* and their presence is generally accompanied with a considerable deposit of uric acid, and also with much free epithelium and epithelial *débris.* These casts often contain many perfect cells of renal epithelium, and not unfrequently blood-globules are entangled in them. ("*Illustrations*," Plate XIV., Fig. 1; Plate XV., Fig. 1*a.*; *see* also Plate XVIII., Fig. 89, of this work.)

Besides these casts, however, some of the larger casts, comprehended in the second class, may often be observed; and these have, as Dr. Johnson states, "a wax-like appearance"; or they may be dark and granular, or part of the cast may be so highly granular as to be quite opaque, while in another portion it may be perfectly clear and transparent. The very wide casts and fragments found in those cases of acute nephritis, in which the kidney was in a sound state before the attack, are probably, wholly or in part, formed in the wide portion of the uriniferous tubes near the papilla. Sometimes also a few of the small "waxy casts" may be observed, and rarely a few of the cells may be found to contain well-defined oil-globules.

365. Casts containing Dumb-Bells.—In the urine of a patient suffering from cholera, after eighteen hours suppression of urine, I found a trace of albumen, with some very transparent casts entangling dumb-bell crystals of oxalate of lime. ("*Illustrations*," Plate XII., Fig. 1.) Octohedral crystals of oxalate were also present in the urine; but none were to be seen in the casts. The presence of dumb-bells in casts proves clearly that these peculiar crystals are formed in the uriniferous tube.

Crystals of triple phosphate and octohedra of oxalate of lime are sometimes met with in casts. Not unfrequently perfectly dark casts are observed. The opaque appearance is due to the presence of urate of soda, which is proved by the fact of the casts becoming perfectly clear and transparent upon applying a gentle heat to the slide upon which the specimen is placed. (Plate XVIII., Fig. 87.) These casts appear white by reflected light.

366. Casts in Chronic Nephritis, a considerable number of "granular epithelial casts," of medium diameter, will be present in

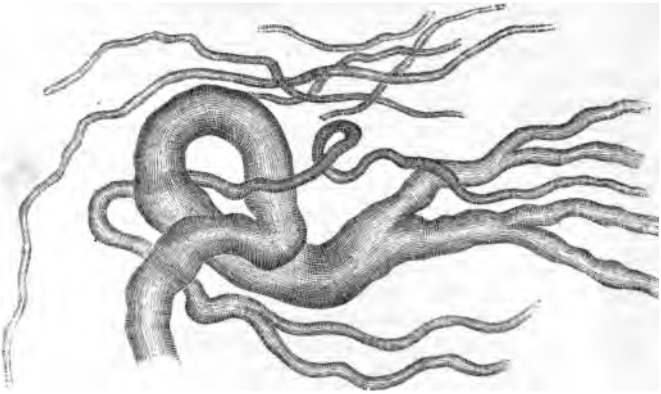
the early stage of the disease. In the second stage, the granular casts become more abundant, and often form a white deposit at the bottom of the vessel.

Dr. Johnson says that, in the third stage, there may be an abundant deposit composed of granular casts and disintegrated epithelium; or secondly, the granular casts may be mixed with large waxy casts, with a sharp and well-defined outline; or thirdly, the waxy casts may be in small number, and mixed with a few granular casts and disintegrated epithelium. Casts from a case of chronic nephritis are represented in Plate XVIII., Fig. 88; *see* also "*Illustrations*," Plate XV., Fig. 2; and Plate XVII.

367. Casts containing Oil.—In that condition of the kidney termed "fatty degeneration," the pale highly albuminous urine which is often passed in considerable quantity, frequently contains a number of casts which appear to be made up of oil-globules, or composed of cells containing oil (Plate XVIII., Fig. 90). In adults recovering from acute nephritis, it is not uncommon to find a few oil-particles in the casts, and cells crammed with small oil-globules floating in the surrounding fluid; but at the same time, if there be a greater number of granular or epithelial casts, the presence of the oil need not excite any apprehension for the patient's safety. If, however, on the other hand, the oil-casts increase while the other casts diminish in number, we shall probably find that the case will become one of confirmed fatty degeneration, and that the acute attack affected a kidney, not previously in a perfectly sound state. The composition of the oil in these cases has been alluded to in § 337. (*See* "*Illustrations*," Plate XVIII., Figs. 1 and 2.)

368. Fat-Cells. Besides the occurrence of fatty matter in casts, and in cells entangled in casts, it is very commonly met with in cells, in the urine; and occasionally these cells are present without any casts. They consist usually of epithelial cells of the kidney, enlarged and gorged with oil. Sometimes they contain a few oil-globules, which are well defined, and are seen to be distinct from each other; while, in other instances, the globules are very minute, and so crowded together that the cell appears perfectly opaque and dark, resembling the so-called 'inflammatory globules.' Although I use the term *cell*, it is not possible in many cases to demonstrate the

Fig. 83.



§ § 105, 346

Fig. 84.

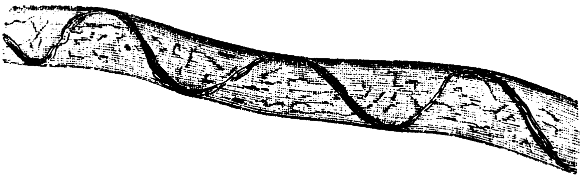


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Fig. 85.

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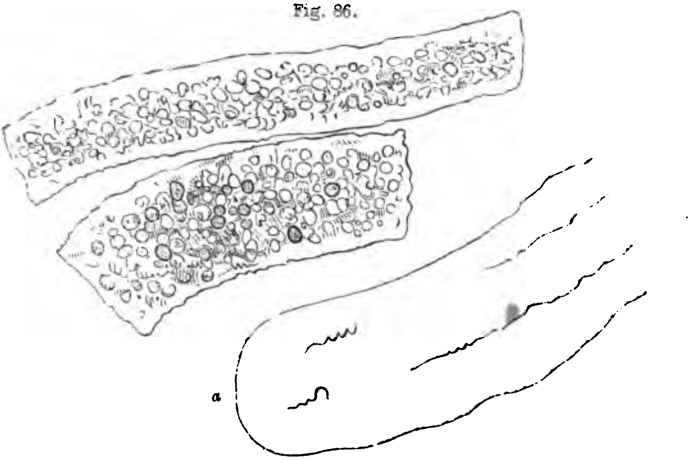
§ 344

Fig. 86.



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the existence of a *cell-wall.* Occasionally, "cells" containing oil-globules may be derived from some other part of the mucous surface of the urinary passages. I have seen epithelial cells, and collections of oil-globules which have been removed from the membraneous portion of the urethra. It is therefore important to bear in mind that cells containing oil-globules are occasionally met with in cases where the kidneys are not diseased.

369. **Casts containing Blood-Globules** are not unfrequently met with in the deposit of the urine in acute nephritis. (Plate XVIII., Fig. 89.) They are usually of medium size, and often contain a certain quantity of epithelium. ("*Illustrations,*" Plate XV., Fig. 1*b*.)

The blood in many of these cases is undoubtedly poured out by the vessels of the Malpighian body. It is extraordinary how determined some observers are in asserting that this hæmorrhage from the Malpighian body into the upper part of the uriniferous tube does not occur, and that "casts" are not formed in this part of the tube. I have *seen* the blood in the convoluted part of the tube, near and in the Malpighian body, and also in the lower straight portion, on several occasions, and I have very often injected colouring matters through the capillaries of the Malpighian body into the tube. In the newt, ("*The Microscope in its Application to Practical Medicine,*" p. 225,) the arrangement may be demonstrated beyond the slightest question. But Henle ("*Zur Anatomie der Niere.,*" Göttingen, 1862) has lately put forward a view upon the structure of the kidney, which, if true, completely upsets all that has been made out of late years, with regard to the minute anatomy of this organ, and necessitates new physiological views; but it seems to me, however, that Henle has not satisfactorily proved the facts which he has advanced. It may be most positively demonstrated in many animals, that Bowman's original description of the course and relation of the uriniferous tube and Malpighian body are perfectly accurate. I am satisfied that, as yet, no one has succeeded in shaking in the least Bowman's original conclusions. Henle's drawings seem somewhat roughly executed, and in this particular, at least, behind the work of the present day in Germany.

370. **Casts containing Pus** are not common, although some

cells agreeing in character with the pus-globule, in the development of two or three little circular bodies in the centre, when acted on by acetic acid, are not unfrequently observed. These cells are no doubt modified cells of the uriniferous tube. Cases in which the urine exhibits these characters are generally acute, and terminate fatally in a short time. A beautiful specimen of the urinary deposit in one of these rapidly fatal cases is represented in Plate XVI. of the "*Illustrations*," *see* also p. 68. At the same time, I should state that I have seen two or three instances occurring in children where these casts and cells were most abundant, which have completely recovered.

B.—Casts of considerable Diameter.

371. **Large Waxy Casts,** of about the one-five-hundredth of an inch in diameter, are obviously derived from tubes which have been entirely stripped of epithelium; for under no other circumstances could casts of this diameter be formed. They are often met with in small quantity in the urine of acute desquamative nephritis; but when present in considerable numbers, a condition of kidney to which Dr. Johnson has given the name of "waxy degeneration," from the peculiar glistening appearance of the substance with which the tubes are filled, is present. Large waxy casts are represented in the "*Illustrations*," Plate XVI., *a* and *b*; *see* also Plate XVII., Fig. 86.

In some cases, however, it is certain that these casts of large diameter are formed in the lower part of the straight portions of the uriniferous tubes where these are very wide. Often it is evident that the material of which the cast is composed is deposited in successive layers, and a small cast, formed high up in the convoluted portion, is sometimes seen in the centre of a large one formed below. In Plate X., Figs. 50 and 51, casts of this kind are represented. Although in some cases the convoluted portion of the uriniferous tube is wide enough to admit of the formation of one of these large waxy casts, I have never seen an instance where the tubes between the cortical and medullary portion of the kidney were large enough to permit them to pass through. There is, however, no reason why this part of the tube should not in some cases of disease, have been dilated sufficienty to allow casts of considerable width to pass. (*See* "*Archives of Medicine*," Vol. I., p. 303.)

C.—Casts of small Diameter.

372. Small Waxy Casts, on the other hand, are derived from tubes in which the epithelial lining is entire, and in which there appears no tendency for desquamation to take place—a condition to which the name of "*non-desquamative nephritis*" has been applied. The urine is either found to contain no deposit whatever, although albuminous, or only some of the small waxy casts, not more than one-thousandth of an inch in diameter, can be found. In some of these cases, symptoms of blood-poisoning come on, and a rapidly fatal result occurs. The casts have a perfectly smooth and glistening surface, and present in the microscope the same general appearance as a piece of the elastic lamina of the cornea. ("*Illustrations*," Plate XIV., Fig. 6.) It is probable that some of these very fine casts come from contracted tubes, and perhaps from tubes which have not attained their full development.

The characters of "transparent mucus casts" have been already referred to, and the chemical composition of casts is discussed in § 105, p. 60.

373. Of Casts in a Clinical Point of View.—It is not too much to say, that the treatment of renal disease has advanced within the last few years more than that of any other class of diseases. Frequently we are able to say most decidedly what course should be followed in a given case; and we can indicate exactly the conditions which will retard the progress of the malady, and warn the patient of those which would certainly hasten the extension of disease. I do not think I have at all exaggerated the improvement which has taken place in this department of medicine; and when we reflect that we possess more positive knowledge of the anatomy and physiology of the kidney, and that its morbid changes have been more successfully investigated than those of other important organs, we can scarcely help attributing the improved treatment to our increased knowledge, and we have every encouragement to hope that ere long a similar result will be seen as distinctly in other branches of medicine. I am quite sure that many patients with chronic renal disease are now kept alive, and even enjoy life, for many years longer than was possible at a time when the exact nature of their malady was not understood, and when the treatment

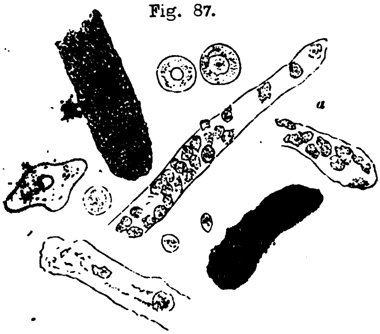
considered right was of a kind which no one, knowing anything of the physiology of the kidney, would now think of adopting.

At the same time we must not express ourselves confidently, if only one or two casts of a particular kind are found. Thus we may meet with, in the deposit of the urine from acute cases, which completely and perhaps rapidly recover, one or two cells containing oil, and one or two casts containing a few oil-globules; but we must not, from the presence of these, be led into the error of concluding that the case will necessarily become one of fatty degeneration of the kidney. If, however, there were *numerous* cells and casts containing oil, such an inference would undoubtedly be correct. We must not expect to find in one case *epithelial casts* alone, in another *granular casts* alone, in a third *fatty casts* alone, in a fourth none but *large waxy casts*, and so on; but we must be prepared to meet with several varieties in one case, and must ground our opinion in great measure upon the relative number of any particular kind of cast, and upon the circumstance of other deposits being associated with the casts. For instance, the presence of uric acid crystals and blood-corpuscles would render it very probable that the case was acute, and of short duration. The absence of these deposits, and the presence of a number of granular or perfectly transparent casts, which can only be seen when the greater part of the light is cut off from the field of the microscope—or the existence of *a number of oil-casts*—render it certain that the case is chronic. The former would indicate that the kidney was becoming small and contracted, while the latter variety of casts occurs when it is often of large size and fatty. Such examples might be multiplied. When we consider how very numerous the secreting tubes of the kidney are, we cannot feel surprised that a different condition should exist in certain cases, in different tubes, at the same time; and, from careful *post-mortem* examinations, we know that very different morbid appearances are often seen in different parts of the cortical portion of one kidney. It is not difficult, therefore, to account for the fact of the presence of casts differing much in their diameter and characters in the same specimen of urine.

The treatment of cases of renal disease in which casts are present in the urine, has been already referred to in § 257.

CASTS OF URINIFEROUS TUBES. PLATE XVIII.

Fig. 87.



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§ 365

Fig. 88.

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§ 366

Fig. 89.

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Fig. 90.

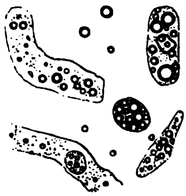

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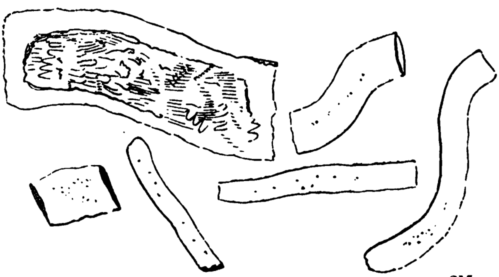
Fig 91.



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CHAPTER XV.

URINE IN DISEASE. III. OF DENSE AND OPAQUE DEPOSITS.—PUS—URATES—PHOSPHATES.—*Of Urates—Urinary Deposits associated with Urates—Urates in Urine, without forming a Deposit: Albumen present—Analyses of Deposits of Urates—Of the Clinical Importance of Urates—Of the Treatment of Cases in which considerable Quantities of Urates are deposited from the Urine.*—PUS—*Characters of the Urine—Tests for Pus—Microscopical Characters of Pus—Of the Presence of Pus in Urine, in a Clinical Point of View—Of the Treatment of Cases in which Pus is found in the Urine.*—EARTHY PHOSPHATES—*Triple or Ammoniaco-Magnesian Phosphate—Tests for the Earthy Phosphates—Deposits associated with Triple Phosphate—Phosphate of Lime—Phosphate of Lime, in the form of Spherules and small Dumb-bells—Of Phosphate of Lime in a Crystalline form—Dr. Hassall's Observations on the Crystals of Phosphate of Lime—Of the Clinical Importance of Deposits of the Earthy Phosphates—Of the Treatment of Cases in which Phosphatic Deposits occur—Peculiar Form of Phosphate, usually regarded as consisting of Triple Phosphate—On the Crystalline Form of Phosphate of Lime.*

III.—SECOND CLASS OF URINARY DEPOSITS.

Substances which are included in the second class of deposits form a bulky, dense, opaque, and often abundant precipitate, which sinks to the bottom of the vessel, leaving a perfectly clear or more or less turbid supernatant fluid.

374. Pus, Urates, Phosphates.—The most important deposits of this class are those consisting of *urate of soda*, *pus*, and *earthy phosphate*, and these three deposits are very commonly met with. To the practitioner, these deposits are especially interesting; and as their presence in the urine is characteristic of morbid conditions differing widely in their results from each other, while the appearance of the deposits to the naked eye is very similar, it is a matter of great importance that he should be able to distinguish them from each other with certainty, and at the same time with facility. Before entering, therefore, upon a detailed description of these bodies, let me draw attention to an exceedingly simple method of distinguishing them. The clear supernatant fluid is to be poured off, and a little of the deposit transferred to a test-tube. Upon the addition of about half the bulk of solution of potash, one of the three following points will be noted:—

1. *No change* will be produced, in which case the deposit consists entirely of *phosphate.*

2. The mixture will become *clear*, and very *stringy* or *viscid*, so that it cannot be poured from the test-tube in drops. In this case, we may be certain that the deposit consists of *pus.*

3. The solution of potash may cause the mixture to become clear, but not viscid, in which case *urate of soda and ammonia* enter very largely into the composition of the deposit.

If liquor potassæ gelatinises the mixture, but does not render it clear, it is probable that both *pus* and *phosphates* are present. In any of the above instances, our conclusion as to the nature of the substance should be confirmed by some of the tests presently to be mentioned, and by microscopical examination.*

Urates of Soda, Ammonia, &c.

375. Urates.—From the researches of Heintz *(Lehrbuch der Zoochemie)* it appears that this deposit, usually termed *urate of ammonia*, really consists principally of *urate of soda*, with small quantities of *urates of ammonia, lime, and magnesia.* It forms the

* I have seen, but not more than on three or four occasions, deposits of *blood* and deposits of *cancer cells* in such large quantity, that they might be included in this class; but it would scarcely be possible, even upon very cursory examination, to mistake either of them for pus, phosphates, or urates. Such deposits, in considerable quantity, are not common. For blood, *see* § 416, and for cancer, § 421.

most common urinary deposit. Heintz and Scherer have shown that upwards of 80 per cent. of the lateritious deposit consists of uric acid. Heintz finds more than 14 per cent. of soda, and less than 1 per cent. of ammonia; while Scherer, in three specimens, obtained only *traces* of soda, the ammonia varying from upwards of 2 to more than 8 per cent. Much difference exists as to the presence of free uric acid in this deposit. According to Heintz, the whole of the uric acid is combined as an acid urate, and, as remarked by Parkes, the constant proportion of uric acid present in this deposit would lead to the inference that it existed in some form of combination. Bence Jones ("*Journal Chemical Society*," 1862) found the urates in healthy urine to be composed of the following constituents. Three analyses were made.

Uric acid . .	94·36	91·06	92·11
Potassium . .	3·15	3·78	5·06
Ammonium . .	1·36	3·36	1·61
Sodium . . .	1·11	1·87	1·20

A small quantity of urate is held in solution in healthy urine; and, in slight derangement of certain chemical changes going on in the body, it is often secreted in such quantity as to be deposited soon after the urine is passed.

Urate of ammonia, when artificially prepared, crystallises in delicate needles; but in this form it is never found in the urine; for, as Bence Jones has shown, the slightest trace of chloride of sodium causes the salt to assume an amorphous character, and increases the solubility of the urate by one-half. Urate of soda is sometimes found in the urine, forming globular masses, from different parts of which sharp spikes of uric acid project. It is probable that these crystals were formed after the globular masses. I believe that in urine passed during a feverish state, the uric acid crystallises with some organic material which causes it to assume the form of spherical crystals. (*See* the observations on dumb-bells of oxalate of lime.) In the urine of children it is very frequently met with in the form of small spherical globules, very like the crystals of carbonate of lime from horses' urine, and these sometimes occur in the adult. Some of the largest spherules I ever saw, which very closely resemble *leucine* in appearance, are figured in the "*Archives of Medicine*," vol. i., p. 249. (*See* also "*Illustrations*," Plate VIII., Figs. 2, 5, and 6.)

In Plate XIX., Fig. 92, some spherules of urate of soda, obtained by concentrating healthy urine, are represented.

Urate of soda is not very soluble in cold, but is readily dissolved by a small quantity of warm water, from which, however, it is deposited as the solution cools. It is readily dissolved by alkalies, and also by solutions of alkaline carbonates and phosphates. Pure urate of soda crystallises in small acicular crystals, which are more or less aggregated together. In this form it is found in the pasty deposits forming chalk-stones in cases of gout. This thick deposit contains much water. In one specimen I examined, the solid matter only amounted to 29·9 per cent., and consisted chiefly of urate of soda.

Deposits of urate of soda vary very much in colour, sometimes occurring as the white or pale "lateritious deposit," or "nut-brown sediment;" while, in other cases, the deposit has a pink, brown, or even dark reddish colour. The amorphous urate is represented in the "*Illustrations*," Plate VIII., Fig. 1. Upon the addition of moderately strong acids, the deposit of urate is slowly dissolved; but, in a short time, a slight granular precipitate may be observed, which, upon microscopical examination, is found to consist of rhomboidal crystals of uric acid. It is not uncommon to meet with specimens of urate deposit which become decomposed after the urine has left the bladder, when numerous crystals of uric acid are deposited. If urate of ammonia be treated with nitric acid, and, after evaporation to dryness, ammonia be added, the beautiful purple colour, owing to the formation of murexide, is produced. This reaction will come under notice when the characters of uric acid are discussed (§ 398). Rubbed with caustic lime, a perceptible odour of ammonia is evolved.

376. Urinary Deposits associated with Urates.—The deposit of amorphous urate is more frequently accompanied with oxalate of lime than with any other salt. It has been shown that urates may be readily decomposed into oxalates after the urine has been passed. The crystals of oxalate are often so minute as readily to escape detection in the abundant deposit of urate, unless the latter be dissolved by the addition of a few drops of solution of potash. *Triple phosphate* is not unfrequently met with amongst the urate, and occasionally a deposit of phosphate of lime has been observed; in which case the reaction of the urine will be neutral, or even alkaline.

Urate of soda is occasionally the cause of the dark granular appearance exhibited by some casts of the uriniferous tubes, as may be proved by slightly warming the deposit, and then examining it with the microscope, when the casts will be found to have become clear.

377. Urates present without forming a Deposit: Albumen present.—Often the urate remains suspended in the urine without forming a visible deposit, and produces a curious opalescence. Sometimes the urine resembles in appearance the so-called chylous urine; but its true nature is readily made out by the application of some of the tests above referred to. (*See* also *Chylous Urine*, § 329.) If albumen be present in urine containing urates, it will not become clear by heat, or rather, the urine will at first clear, but soon become turbid again, in consequence of the precipitation of the albumen. With a little care, however, in applying heat, the upper stratum of urine in the test-tube may be made hot enough to coagulate the albumen, the middle stratum being *cleared* by the solution of the urate without the albumen being thrown down, while in the bottom of the tube the deposit remains unchanged. In performing this experiment, the test-tube must be held at its lower part.

378. Analyses of Urine containing Deposits of Urates.—The urine of a child suffering from scarlatina, with delirium and unconsciousness, contained an abundant deposit of urates. It was acid; specific gravity, 1,025.

Analysis 66.

Water	932·2	
Solid matter	67·8	100·
Organic matter	59·03	87·07
Fixed salts	8·77	12·93
Uric acid	1·19	1·75

In a deposit which was composed of rounded globules, with small sharp spicules projecting from them (uric acid), I found the following constituents: phosphate of lime, urate of soda, and other urates. A considerable quantity of these spherules existed in the urine of a man suffering from pneumonia, and they had the following chemical characters. There was distinct evidence of the presence of uric acid by the murexide test. The deposit was soluble in boiling potash; and when, to the alkaline solution, excess of hydrochloric acid was

added, well defined crystals of uric acid were formed. Upon exposure to a red heat, an odour like that of burnt horn was exhaled ; and, after decarbonisation, a moderate quantity of a white ash remained, which dissolved in acids with effervescence; and from the acetic acid solution a precipitate was thrown down, upon the addition of oxalate of ammonia. I conclude, therefore, that urate of lime entered into the formation of these crystals. The quantity of crystals at my disposal was far too small to make a quantitative analysis.

379. Of the Clinical Importance of Urates.—The amorphous deposit of urate is the commonest of all urinary deposits, and, indeed, is occasionally present in the urine of everyone, but is much more frequently passed by some persons than others. If present in the urine from day to day, and especially if it be in considerable quantity, it is right to interfere, for it is a clear indication that the chemical changes connected with the processes of oxidation are at fault. Imperfect action of the skin, highly nitrogenous diet, little exercise, close rooms, too much wine or beer, will almost always cause this deposit to appear. In an ordinary cold, the deposit is very generally observed. The general conditions which determine the presence of an increased quantity of urates are the same as those which cause excess of uric acid. But with regard to "*excess*," the observations made in § 237 must be borne in mind. There may be a *deposit* without *excess*, and there may be *excess* without any deposit whatever. Deposits of urates are very common in many cases of heart disease, emphysema, and chronic bronchitis. It is probable that the passive congestion of the liver and the slow circulation of the blood through this organ has much to do with the formation.

These deposits are almost always present in febrile conditions; and an enormous deposit of urates, sometimes red, sometimes pale, marks the occurrence of 'resolution' of many acute inflammatory attacks. A "critical deposit of urates" is seen commonly enough in acute pneumonia, scarlatina, continued fever, rheumatic fever, &c. It need scarcely be said that no special treatment is required to prevent the formation of the deposit in such a case. In many of these acute cases I am in the habit of giving very large quantities of acetates or citrates. In pneumonia I often give as much as 12 ounces of the liquor ammoniæ acetates in the 24 hours. No doubt by this treatment many imperfectly oxidised products, and urates amongst the number, are eliminated.

380. Of the Treatment of Cases in which Considerable Quantities of Urates are Deposited from the Urine.—An increased quantity of fluid and a little bicarbonate of potash or soda, or liquor potassæ, will generally cause the disappearance of these deposits. Often the liver is inactive, in which case a small dose of calomel or blue pill, muriate of ammonia, or solution of acetate of ammonia, will set matters to rights. Some people make themselves very nervous about the appearance of this sediment. A little more exercise in the open air, moderation in diet, simple food, a little less wine than usual, with no beer, and a glass or two of Vichy or potash water with the dinner and the last thing at night, will generally have the desired effect. All sorts of remedies have been devised for the treatment of this condition. Benzoic acid and benzoate of ammonia, among other things, have been given with advantage.

In cases where the ordinary remedies fail, a number of others which will suggest themselves to the practitioner may be tried if he bears in mind the conditions under which this deposit occurs, and inquires carefully into the general habits of the patient.

Many of the salts of vegetable acids do good in cases where urates are deposited day after day; and many fruits, such as apples, strawberries, oranges, lemons, grapes, &c., may be taken. The salts of these vegetable acids become converted into carbonates in the organism, and they may be given in cases in which alkalies derange the action of the stomach. Phosphate of soda is often prescribed, and benzoic acid has been strongly recommended by Mr. Ure; but it is of the greatest importance, when these deposits are constant, and especially when associated with rheumatic pains, to pay attention to the action of the skin and bowels. The vapour bath, the hot air bath, and the Turkish bath, are of great service by promoting sweating. The vapour bath is sufficiently potent, and does not produce depression.

Pus.

381. Pus in the Urine is not found in the healthy urine of children and adults, although it is very frequently met with in the urine of persons past the middle period of life whose general health is good. The changes which occur in the cells of a healthy mucous

membrane when they give rise to pus-corpuscles instead of to cells like themselves, are now well understood. It is remarkable that such a change may take place without the essential purposes of the mucous membrane being interfered with. The portion of the genito-urinary mucous membrane most frequently affected in this way is undoubtedly the urethra, and I believe, next to this, that of the ureters and pelvis of the kidney; while the functions of the bladder, as a general rule, become seriously deranged before its mucous membrane forms much pus. To this last statement there are, however, exceptions.

The formation of pus-corpuscles in the cells of vaginal epithelium is represented in Plate XIX., Fig. 98. That an enormous quantity of pus may be formed in the pelvis of the kidney and in the infundibula without seriously interfering with the general health of the patient, is a fact which has been proved by many cases. I particularly remember two female patients who, for upwards of a twelvemonth, had been passing urine a fourth part of the bulk of which consisted of pus. These patients had not suffered in nutrition or in general health, and one had gone through her occupation as servant during several months.

The urine of men after the age of forty often contains a greater or less number of pus-corpuscles—a fact of which I was not aware until I had subjected the urine of a great many hospital patients indiscriminately to examination. In private practice the same point is noticed very frequently. It is, indeed, more common to find a few pus-corpuscles in the urine after this period of life than to find it free from them. The fact is important, and shows that the existence of pus in the urine must not, *per se*, be regarded as evidence of serious disease.

Dr. Balfour of Edinburgh has published two cases, in which he thinks the pus came from the prostate gland, and considers that it is not unfrequently derived from this source in certain cases in which it is clearly not formed in the kidneys, ureter, or bladder ("*Edinburgh Medical Journal*," Vol. 1, p. 612.—1856.) In confirmation of this conclusion, I may remark that I have often seen pus-like cells in the follicles of the prostate, and such cells often form the nucleus, around which the hard matter of prostatic calculi is deposited.

382. Characters of the Urine.—Pus generally forms an opaque

cream-coloured deposit, which sinks to the bottom of the vessel, the supernatant fluid being generally slightly turbid from the presence of a few pus-globules. The deposit, however, readily diffuses itself again by agitation. The urine will always be found to contain a little albumen derived from the liquor puris. If, however, the albumen exist in large quantity it is probably derived from the kidneys.

If the urine be alkaline, the pus is no longer present as a cream-coloured deposit, but exists as a gelatinous or stringy mass, which adheres firmly to the sides of the vessel containing it. It is to this glairy mass that the term *mucus* has been, and even still is, carelessly applied. The viscid, glairy, mucus-like deposit arises from the carbonate of ammonia, set free by the decomposition of urea, reacting on the pus-globules in a manner similar to that in which potash behaves.

383. Tests for Pus.—The tests which may be relied upon for detecting the presence of pus in urine, are, the addition of solution of potash to the deposit; and of nitric acid, and the application of heat to a portion of the supernatant fluid, in order to detect the presence of albumen. Cases from time to time come under notice, in which, although the amount of albumen is not great, the quantity, nevertheless, appears to be in too large a proportion to the pus-cells present, to belong entirely to the liquor puris. In such a case, there would be a suspicion of kidney-disease, and the deposit of the urine should therefore be very carefully examined for casts of the tubes.

384. Microscopical Characters of Pus.—In those cases in which the pus is in too small quantity to be detected by chemical tests, we must rely upon the microscopical examination of the deposit, and the development of two or three small round bodies in the centre of each pus-globule upon the addition of a drop of acetic acid. Pus-globules always have a granulated appearance in the microscope, and, when fresh, do not always exhibit a well-defined nucleus; the outline is usually distinct and circular, but it is finely crenated. Upon the addition of acetic acid, the globule increases somewhat in size, becomes spherical, with a smooth faint outline; and from one to four nearly circular bodies are developed in the centre of each. Pus-corpuscles are represented in Plate XIX., Fig. 93; and in Figs.

94, 96, pus-corpuscles treated with acetic acid, showing the nuclei very distinctly, are figured. Pus-corpuscles found upon the mucous membrane of the urethra, bladder, and vagina, often exhibit little protuberances, and these are formed by the moving outwards of the living or germinal matter of which the pus-corpuscle is almost entirely composed. The nucleus has nothing to do with these *vital movements*, such outgrowths often increase, move away from the parent mass for some distance, and at length become detached. It is in this manner that pus-corpuscles multiply. The process occurs in precisely the same way in mucus, young epithelial cells, and in every kind of germinal matter. Pus-corpuscles thus increasing, are represented in Plate XIX., Figs. 97, 99, under a power of 700 diameters, and in Fig. 120, Plate XXII., a cell of bladder epithelium is dividing the two.

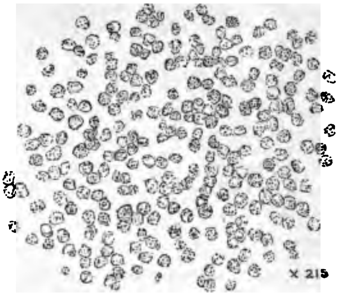
385. Of the Presence of Pus in Urine in a clinical point of view.—From what I have already said it will be inferred that the presence of a few pus-corpuscles in urine is a fact which need not excite alarm; that the mucous membrane of the urethra may become affected in a slight degree like some other mucous membranes, and that pus-corpuscles may be formed in small number upon its surface, without any material impairment of structure or derangement of function resulting. In the urine of the female, it is very common to find small quantities of pus which are derived from the mucous membrane of the vagina, and in some women the formation of pus is almost constant. When, however, pus is found in the urine in sufficient quantity to form a deposit visible to the naked eye, it should excite our attention. The fact will probably bear in a very important manner upon the diagnosis of the case. Pus may be derived from any part of the genito-urinary mucous membrane; from the surface of the *urethra;* from the *prostate;* from the *bladder*, or from the *follicles of the mucous membrane* in these parts; from the *ureters;* from the *pelvis of the kidney*, or from the *secreting structure of the organ.* The pus may also come from an *abscess* opening upon any part of the surface of this mucous membrane.

It is often difficult to form an opinion as to the exact seat of formation of the pus; and it must be obvious that we ought never to come to a decision on such a point until we have accurately weighed all the evidence that a careful investigation of the case will

Fig. 92.

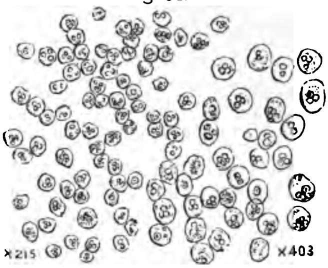
§ 375 × 215

Fig. 93.



§ 384

Fig. 94.



§ 384

Fig. 98.

§ 387 × 215

Fig. 95.

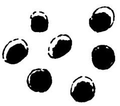
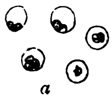
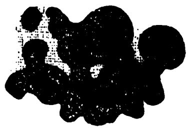


Fig. 96.



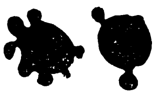
§ 384 × 215

Fig. 99.



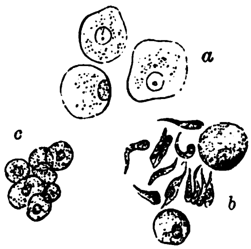
§ 384 × 700

Fig. 97.



§ 384 × 700

Fig. 100.



§ 353 × 215

Fig. 98.

§ § 355, 384 × 215

To face page 322.

afford. Microscopical examination will give us important help; but we must not rely solely upon this, or indeed upon any single mode of investigation. The question is an extensive one, and I shall only refer to one or two points connected with the evidence deduced from microscopical examination. Some idea of the locality from which the pus has been derived may often be formed by examining attentively the characters of any epithelial cells which may be mixed with it (§ 353). When pus is derived from the bladder, it generally contains crystals of triple phosphate, and granules or small spherules of earthy phosphate; and the symptoms of the case will generally enable us to decide if the pus be formed in this viscus. Large quantities of pus may escape from the bladder for a number of years. I know of one gentleman who has passed pus in considerable quantity from the bladder during a period of twenty-five years. The suppuration of the bladder may be due to gonorrhœa, to gout, and to a state of mucous membrane, which is termed catarrh of the bladder. It commonly arises from stricture, the contraction interfering with the free escape of the urine from the bladder, and oftentimes preventing the complete evacuation of this organ. If the stricture be dilated, the state of the bladder is often completely relieved.

When the pelvis of the kidney is dilated and sacculated (a form of pyelitis), the quantity of pus passed in the urine is often enormous; and this may last for years, until the kidney becomes a mere pus-forming cyst, which, in favourable cases, gradually contracts,—the formation of pus ceases,—the cyst slowly wastes,—and the patient perfectly recovers,—the work of the two kidneys being performed by the remaining one, which has gradually undergone an increase in size corresponding to the increased work it has been called upon to perform. When pus is derived from the pelvis of the kidney, crystals of earthy phosphates are often absent. I have seen five cases of this condition occurring in domestic servants. One was under treatment for a twelvemonth, and completely recovered. I have now (1863) a case of this disease in the hospital. The girl, who is also a servant, has been passing large quantities of pus daily for ten months. The proportion passed in twenty-four hours usually occupies the bulk of eight ounces, and sometimes amounts even to a larger quantity than this. It is very remarkable in these cases that the formation of this large amount of pus is not associated with

hectic, and, in many cases, the general health continues good, the strength being supported with tonics and a generous diet.

There is a chronic state of ulceration of the ureters and pelvis of the kidney and bladder, in which pus is formed in considerable quantity, leading to the most distressing symptoms. Pus may depend upon the existence of old stricture.

Abscesses form in the kidney as in other organs; and, after the abscess has burst, pus makes its way into the urine. The inflammation of the mucous membrane of the kidney often extends upwards from the bladder.

The presence of a calculus in the kidney, in the ureter, or in the bladder, may set up inflammation which may go on to the formation of pus. A very small calculus will sometimes excite great irritation in the kidney, so that both pus and blood are voided in the urine.

Pus may be derived from a sloughing process going on in the kidney. Sometimes a portion of the organ sloughs off entire in these cases. My friend, Mr. Newham of Bury St. Edmunds, sent me a short time since a piece of kidney which had sloughed off, and passed with much pus into the urine. Pus may also depend upon the presence of cancer in the kidney or upon tubercle developed in the same situation.

Pus may come from an acute affection of the uriniferous tubes, and the corpuscles will be found free in the urine, and entangled in considerable number in casts. These cases are often very rapidly fatal. (See "*Illustrations*," Plate XVI.)

Pus formed upon the mucous membrane of the vagina as takes place in leucorrhœa has been already considered.

In women, a large quantity of pus may be formed in burrowing abscesses amongst the pelvic viscera, and make its way into the bladder, ureters, or vagina. These cases of *pelvic cellulitis* are not uncommon, and I have seen a patient who was reduced to an extreme state of emaciation from the long continued drain, completely recover, although there were openings, both into the rectum and upper part of the vagina, so that sometimes pus passed by the bowel, and sometimes it was found in the urine.

386. Of the Treatment of Cases in which Pus is found in the Urine.—The full consideration of this subject, it need scarcely be said, would occupy a volume. I shall, therefore, only allude

briefly to the treatment of some of the cases which naturally fall to the province of the physician to treat. But I would remark, generally, that the treatment of many cases which are usually considered to require special medicines, may be conducted successfully upon a much more simple plan than that usually recommended in treatises upon medicine. For example, how many remedies have been considered specifics in gonorrhœa, and yet the disease very frequently gets well very soon under complete rest, mild purgation, alkalies, and sudorifics. The most obstinate cases of gleet, which have been subjected to various remedies and injections of different kinds, often recover if the general health of the patient be improved by tonics. The common tincture of sesquichloride of iron and quassia persevered in regularly for several weeks is particularly valuable in these cases, and it is more than probable that the benefit results from the improvement in the general health.

Among the most obstinate of the conditions which give rise to the presence of pus in the urine, is chronic inflammation of the bladder, not dependent upon stone. This is often called catarrh of the bladder, and, in many cases, is undoubtedly connected with a gouty state of system. I have had considerable experience in the treatment of this condition, and am satisfied that by far the most successful plan is to attend to the general health, and not to trust to remedies which are considered to exert a specific action upon the diseased mucous membrane.

Many cases of chronic disease of the bladder that I have seen, have been subjected to all kinds of treatment, but not one plan has been persisted in for a sufficient time for any benefit to result. A patient is ordered, perhaps, uva ursi for a week; then, being no better, it is changed to buchu, pareira, or chimaplida, next acids are tried with or without some tonic infusion;* then alkalies, and so on; while, in the mean time, the patient has lost his appetite, and has gradually got weak, and perhaps has night sweats. As the disease continues unabated he begins to lose hope, and suffers more

* An infusion of the root of common couch grass (*triticum repens*) has been strongly recommended by Mr. Henry Thompson, as a valuable remedy in cases of irritable bladder depending upon various causes. The proportion is an ounce of the dried rhizome to a pint of boiling water. The patient may take from 12 oz. to a pint of the infusion in 24 hours. Triticum repens has been incorrectly called the "common bindweed," but the plant usually known as "bindweed," is the large convolvulus with white flowers (*convolvulus sepium.*) I have not yet been able to form any conclusion as to the value of this remedy from experience, but Mr. Thompson considers it better than buchu, and speaks of it in high terms. (*See* Mr. Thompson's paper in the "*Lancet,*" October 12th, 1861.)

and more from pain and the irritability of the bladder. The attention being necessarily directed to the ailing organ, the condition often seems to the patient far worse than it really is. If unchecked, the above-mentioned conditions react upon each other, and the patient gets worse. The quantity of pus found in the bladder increases considerably, and the calls to micturate are incessant.

Now, in such a case, it often happens that, if the stomach be set right by dilute acids and pepsine—if stimulants, which, perhaps, have been withheld altogether, be given in moderation at meals—if the diet be simple but nutritious—if the patient take moderate walking or carriage exercise in the open air, especially if he be sent to a pleasant part of the country, or to the sea-side, where he can at the same time be amused—if he be ordered the tincture of the sesquichloride of iron, beginning with ten drops, and gradually increasing the quantity to half-a-drachm three times a-day, in infusion of quassia,—a great improvement may take place in a few weeks. The night-sweats cease, the patient gains in strength and increases in weight, and is able to retain his water for three hours or longer, while the proportion of pus formed is considerably lessened. I have seen patients put upon this plan steadily improve for six months, and I have given the iron regularly for a twelvemonth, in some cases, with real benefit. In fact it will often happen, that a patient will resume the remedy himself, after having given it up, than which there can be no stronger evidence of its usefulness. It is true that many patients get tired of taking one remedy for so long a time, unless the improvement is decided and obvious. It too often happens that, by giving way to a patient's caprice in trying this thing and that, valuable time is lost. The patient might have been relieved, by steady perseverance in a common-sense course, in less time than he has spent in trying first one reputed remedy and then another, in the hope of relieving, immediately, a chronic malady, although it is physically impossible that healthy action can be restored, except by a very gradual progressive change, which requires considerable time for its completion.

It is clearly right, in such a disease as this, to tell a patient at once that he cannot recover in a week; and it is wrong to allow him to think that, by any special remedy, the disease can be cured as by an antidote. If patients, who are utterly ignorant of the nature of the malady from which they are suffering, will obstinately persist in

acting according to their own prejudices, and insist upon being misled, to their own detriment, as some undoubtedly will, it is out of our power to help them. All that can be said is, that, if they had any real knowledge of physiology and medicine, they would have had more confidence in us than in an ignoramus who promises a rapid cure, and is ignorant of the nature of the disease.

In all bad cases, more especially if the pus is ever converted into the ropy mucus-like mass *in the bladder*, it is of the first importance to use injections of warm water. This is a very simple operation, and affords, even in extreme cases which cannot be cured, the greatest relief. Some use injections of dilute nitric acid (one drop of the strong acid to each ounce of water), but the chief benefit, I believe, arises from removing the decomposing matter which irritates the mucous membrane and excites decomposition in the fresh urine as fast as it reaches the bladder, so that plain water (warm distilled or rain water) answers, in almost all cases, perfectly well. It may be injected through a double catheter, or through an ordinary catheter, and drawn off by the same instrument. The bladder should, of course, never be fully injected, as distension of its coats always does harm. In bad cases it is necessary to wash out the bladder in this way every day.

In all cases in which the formation of a considerable quantity of pus goes on in any part of the organism from day to day, it is of the first importance to pay attention to the general state of the patient's health, and experience has proved that the remedies which do most good are those included under the head of tonics. In many cases, too, stimulants are required. The quantity of pus varies from time to time, and it will be found that it increases if the blood becomes poor, while the formation of pus diminishes as the patient's health improves. A greater quantity of material becomes pus when the system is weak and low, than when the nutrition of the body has improved. This fact has been explained in different ways. It seems to me probable that, when the blood is poor, transudation of nutrient matters occurs more freely than in the opposite condition; and it is, I think, mainly in this way that iron, many tonics, and alcohol, act favourably. The pus grows the faster the more it is supplied with nutrient matter, and it takes pabulum which is really required by the other tissues. The pus lives faster than any healthy tissue.

Cases of sacculated kidney require perfect rest, nutritious diet,

and tonics. For the treatment of the different forms of pelvic cellulitis, I must refer to works upon the diseases peculiar to women.

The treatment of calculus in the kidney will be discussed in Chapter XVIII.

Deposits of Earthy Phosphates.

The earthy phosphates soluble in acids, but insoluble in water and alkaline solutions, which are most commonly met with as deposits in urine, are, the ordinary *triple* or *ammoniaco-magnesian phosphate*, or the *phosphate of ammonia and magnesia;* and the *phosphate of lime.*

387. Of Triple or Ammoniaco-Magnesian Phosphate.—The triple phosphate crystallises in two or three different forms. The most common form is that of the triangular prism, with obliquely truncated ends; but these are sometimes complicated by the bevelling of the terminal edges. Not unfrequently the crystal is found much reduced in length, and the truncated extremities become so approximated as to give the appearance of a square the opposite angles of which are connected by straight lines; and thus an appearance very closely resembling that of an octohedral crystal of oxalate of lime is produced. Crystals of triple phosphate are very frequently deposited from *acid urine;* and, when clear and unmixed with other deposits, they form a most beautiful microscopic object. (Plate XIX., Fig. 98.)

388. Tests for the Earthy Phosphates.—If ammonia be added to fresh urine, or to a solution of phosphate of soda and sulphate of magnesia, ammoniaco-magnesian phosphate is precipitated in the form of beautiful stellate crystals, as I mentioned when speaking of healthy urine, and phosphate of lime is thrown down in the form of a fine granular amorphous precipitate.

Ammoniaco-magnesian phosphate is slightly soluble in pure water, particularly if it contain carbonic acid. It is insoluble in solutions of ammoniacal salts. Heated in the blowpipe flame, ammoniaco-magnesian phosphate evolves a disagreeable odour of ammonia, and afterwards fuses, producing a whitish enamel. If the *phosphate of magnesia* thus formed be dissolved in a little dilute acid, the triple salt may be again formed upon the addition of ammonia. The presence of phosphoric acid can readily be proved by the appropriate tests.

389. Deposits associated with Triple Phosphate.—Ammoniaco-magnesian phosphate seldom occurs alone as a urinary deposit. Its presence is often associated with urate of ammonia, and sometimes with uric acid. I have also observed crystals of oxalate of lime mixed with those of triple phosphate. In highly alkaline urine, it is usually accompanied with pus and phosphate of lime.

390. Phosphate of Lime occurs commonly as minute granules, and small spherical masses or angular particles, and it may also be noticed in the form of minute dumb-bells—an appearance probably due to the adhesion of two little spherules, which afterwards become coated with a fresh deposit of the phosphate. Phosphate of lime also occurs in urine in a crystalline form, as was first demonstrated by Dr. Hassall. Phosphate of lime is usually associated with the triple salt—always, if deposited from alkaline urine. In cases of disease of the bladder, in which the urea becomes very rapidly decomposed into carbonate of ammonia, much amorphous phosphate of lime and crystals of triple phosphate are precipitated. It must not, however, be supposed that highly alkaline urine *necessarily contains* a very large *excess* of earthy phosphate; for often an excessive quantity of the salts have been found *dissolved* in acid urine, in which case the excess can only be discovered by chemical analysis. (*See* Analysis 44, p. 188.) When the secretion is alkaline, the phosphates are always precipitated, and become visible to the naked eye as a deposit.

Phosphate of lime dissolves in strong acids without effervescence; and from this solution is precipitated in an amorphous form, upon the addition of ammonia. The salt is infusible before the blowpipe, unless mixed with triple phosphate; and its fusibility increases according to the quantity of the latter salt present. The lime may be recognised in the usual way by the addition of a solution of oxalate of ammonia to a solution of the salt in acetic acid.

Phosphate of lime is soluble in albumen; indeed, it is by reason of its solubility in this substance that the phosphate of lime formed by the action of phosphoric acid on the egg-shell becomes applied to the formation of the osseous system of the embryo chick. Mucus also is a solvent of this salt, and from the mucus of the gall-bladder a considerable quantity is deposited as decomposition proceeds (Plate XX., Fig. 101).

391. Phosphate of Lime in the Form of Spherules and small Dumb-bells.—Deposits of phosphate of lime are generally granular; but after a deposit has been allowed to stand for some days, little spherules are very frequently found, and it is also not uncommon to meet with small dumb-bell crystals. Crystals of the latter character are very often deposited in decomposing mucus, derived from several mucous surfaces, as well as in that of the urinary mucous membrane. Some of the largest of these dumb-bell crystals of phosphate of lime are represented in Plate XX., Fig. 102, They were found in the urine of a patient suffering from continued fever, under the care of Mr. Carver of Cambridge, who sent me the specimen.

A peculiar form of deposit of earthy phosphate is represented in Plate XX., Fig. 103. It consisted partly of phosphate of lime, and partly of triple phosphate. There were no true crystals, neither was the deposit in a pulverulent form. The little angular masses represented, were the only bodies found in this peculiar deposit.

392. Of Phosphate of Lime in a Crystalline Form.—A phosphate of the form represented in Plate XX., Fig. 104, is not uncommonly found in urine. I have not been able to connect its presence with any special state of the system, nor to ascertain the conditions upon which its deposition depends. It is very frequently associated with oxalate of lime, and occurs in acid urine. A considerable quantity of these crystals were deposited from the urine of a man who had a rough oval calculus, composed of oxalate of lime, impacted in the ureter. The case is given in Dr. Todd's "*Clinical Lectures*," 2nd ed., p. 562. They were examined as follows:—

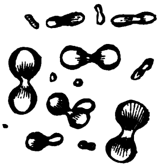
(March, 1851.) "The deposit from about a pint and a half of urine was well washed with water and alcohol, and filtered; it was then dried, incinerated, and decarbonised. The form of the crystals had not been materially altered by the ignition; for, when examined by the microscope, scarcely any change could be observed.

"A portion of the decarbonised crystals were dissolved in dilute hydrochloric acid (they were only very slowly soluble in acetic acid).

"1. Ammonia and potash produced gelatinous precipitates.

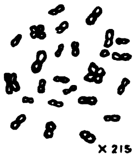
"2. Chloride of barium caused a slight precipitate in the acid solution; but, upon the addition of excess of ammonia, a bulky white precipitate occurred.

Fig. 101.



§ 391 × 215

Fig. 102.

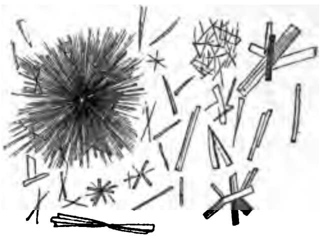


§ 391

Fig. 103.

§ 391 × 215

Fig. 104.

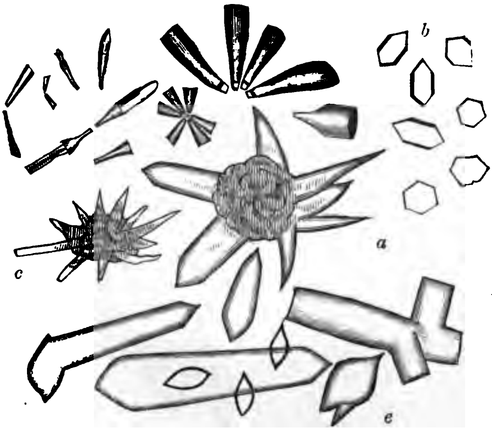


§ 392 × 215

Fig. 105.

§ 397 × 215

Fig. 106.



§ 397 × 215

To face page 330

"3. After the addition of ammonia and re-solution of the precipitate by acetic acid, oxalate of ammonia was added, and a white granular precipitate was produced.

"4. After the addition of nitrate of cobalt and ignition in the blowpipe flame, a beautiful blue was given to the mass." This reaction usually occurs with phosphate of lime, as well as with alumina. These crystals then consisted principally of phosphate of lime.

In another case which I examined, the crystals also appeared to consist principally of phosphate of lime. They were dissolved in nitric acid, and ammonia added. An *amorphous* precipitate occurred; but no crystals were formed after the lapse of some hours. After separation of the lime by oxalate of ammonia, and filtration, ammonia and phosphate of soda were added. A very few crystals of triple phosphate formed after the lapse of some time. There was an abundant precipitate of oxalate of lime.

In other cases, a phosphate of magnesia seemed to predominate. From not being able to make satisfactory quantitative analyses, owing to the small quantity of the salt obtained for examination, I was unable to determine the exact nature of these crystals. They are, as I before said, found in acid urine; and phosphoric acid, lime, and magnesia are present. These are probably the crystals which were regarded by the late Dr. Golding Bird as "small calculous concretions and simple stellæ of the neutral salt." I have seen these crystals in urine of persons suffering from no particular malady whatever, and I have not been able to connect their presence with any particular pathological state. The crystals are not generally found for many days together.

393. Dr. Hassall's Observations on the Crystals of Phosphate of Lime.—Dr. Hassall, in an interesting paper published in the "*Proceedings of the Royal Society,*" Vol. X., p. 281, Jan., 1860, has stated that phosphate of lime is very commonly found in deposits from human urine in a crystalline form. He gives quantitative analyses of four specimens of deposit which contained the phosphates in the following proportions:—

Bibasic phosphate of magnesia	0·15	0·47	4·30	
Bibasic phosphate of lime .	1·85	6·18	5·41	1·96
	2·00	6·65	9·71	

This author states that Dr. Golding Bird's "penniform" crystals of ammoniaco-magnesian phosphate are really a modification of those of phosphate of lime. The crystals represented by Dr. Hassall in Fig. 1 appear to be similar crystals to those I have delineated in Fig. 35, the chemical composition of which I have alluded to. (*See* also "*Illustrations*," Plate XXII., Figs. 1, 2, 3, 4, 5, 6.) I have never obtained these crystals in sufficient quantity for a quantitative examination, but have examined several specimens qualitatively, and have found that they contained ammoniaco-magnesian phosphate, as well as phosphate of lime. The latter was by me erroneously regarded as the less important constituent of the crystals, and the form and crystalline properties of the salt were referred to the triple phosphate. If, however, the crystalline form of the pure salt in Dr. Hassall's fourth analysis is represented in his Fig. 1, the composition of these crystals is determined, and the phosphate of magnesia obtained in some of my examinations must be regarded as an impurity, and not as a necessary constituent.

But Dr. Hassall, in the paper above referred to, goes so far as to say "that phosphate of lime, in the form of crystals, is of much more frequent occurrence in human urine than the triple phosphate, excluding those cases of the presence of the latter phosphate which are due to the decomposition of the urea of the urine subsequent to its emission"; and that "granular calcareous deposits are much more rare than the crystalline." Now, in these statements, I think he will find that few observers will agree with him; for that the ordinary crystals so commonly present in the urine, and usually termed triple phosphate, are actually composed of that salt, there cannot be the smallest question. Crystals of exactly similar form may be readily obtained artificially. The salt is easily obtained from any urine by precipitation by ammonia, and is often found very nearly pure, in large quantity, in urinary calculi. That these crystals, so familiar to everyone, are more frequently met with than any other form of earthy phosphate, crystalline or non-crystalline, I conclude no one will deny. That phosphate of lime often occurs in urine in an amorphous form, and not unfrequently in little spherules and small dumb-bells, as have been figured; and that, when thrown down from its solutions, the deposit is amorphous; and that in calculi it is amorphous—are facts generally assented to, and they have been repeatedly confirmed. It seems to me that these circumstances

militate against the conclusion arrived at by Dr. Hassall as to the relative frequency of the crystalline forms of phosphate of lime and triple phosphate. Nor have I been able to confirm Dr. Hassall's observations upon the pathological importance of these deposits of phosphate of lime. It is a fact that in the majority of cases in which real "excess" of phosphate of lime exists in the urine, it is excreted in solution, and does not form any deposit at all.

Phosphate of lime may be readily obtained in a crystalline form by adding a few drops of chloride of calcium to urine (Bence Jones). I have succeeded in causing this and many other substances which do not readily crystallise, to assume most perfect crystalline forms in glycerine. If a little chloride of calcium be dissolved in a drop of glycerine, and a little phosphate of soda in another drop, and the two drops be allowed to intermix very gradually under thin glass upon a slide, most beautiful crystals of phosphate of lime will make their appearance in the course of a few days.

On the crystalline forms of phosphate of lime in urine, *see* also the papers of Dr. Bence Jones ("*Chem. Society Trans.*," 1861) and the paper of Dr. Roberts ("*Brit. Med. Journ.*," March 30th, 1861).

394. Of the Clinical Importance of Deposits of the Earthy Phosphates.—The conditions under which an excess of alkaline phosphates occurs, have been already considered in Chapter X., and I have also referred to cases of mollities ossium, in which an excess of the earthy phosphates was excreted in the urine (§ 236). The remarks made upon the question of "*excess*" of a constituent and its precipitation as a visible deposit, must be borne in mind. In the great majority of cases in which there is a deposit of earthy phosphates, there is no "*excess*" at all, and the deposition depends upon the urine being neutral or less acid than usual, or upon the decomposition of the urea, and consequently, the formation of carbonate of ammonia after the urine has left the bladder (*See* § 382). It is common enough to find triple phosphate in the urine in cases of dyspepsia, perhaps from the secretion of too large a quantity of highly acid gastric juice or from the formation of other acids.

In various cases of disease, arising from more or less complete paralysis of the nerves, owing to changes occurring in the nervous centre itself, or at the distribution of the nerves in the mucous membrane, the action of the bladder may become impaired and it

may fail to expel its contents completely. The urine thus retained sometimes undergoes change in the bladder, and the mucous membrane suffers in consequence. Earthy phosphate is precipitated, and the condition thus induced, without interference, gradually increases, leading to the state of bladder referred to on page 324.

There are cases in which phosphates are deposited upon every part of the urinary mucous membrane,—bladder, ureters, and the pelvis of the kidneys, apparently depending upon changes which result originally from some affection of the nerves. Although the formation of epithelium and all the essential phenomena of nutrition and secretion may take place, independently of nervous action, it is quite certain that the regularity of these changes, the even flow of nutrient pabulum, and the regulation of the proper proportion distributed, are determined by the nerves. Hence, it follows, that if the nerves, distributed to a structure, be destroyed, or their action impaired, directly or indirectly, the tissue soon suffers, its structure becomes altered, and its function imperfectly performed.

Some of these cases, perhaps the great majority, are due to local disease, for that condition known as chronic inflammation, affecting one part of the mucous membrane, is very prone to spread. It may extend from urethra to bladder, and even into the ureters and pelvis. A rough almost ulcerated state of the mucous membrane may spread in the opposite direction—from the kidneys towards the bladder. In all cases, the urine in contact with a small portion of such altered surface would be decomposed and its earthy phosphates precipitated. These, with the epithelium and mucus of the part, would form irregular projections and intervening depressions, in which more urine would be decomposed; and so the process might proceed, unless the nutritive changes taking place below the surface return to a perfectly healthy state, when the matter deposited would soon be thrown off, the even growth of new healthy epithelium would proceed below, and the surface would again assume its smooth healthy character. For this reason, in such cases, it is of the first importance to pay attention to the general health, for it is obvious that if the blood be in an unhealthy condition, the action and nutrition of the nerve-centres will suffer, in which case, the normal state of the mucous membrane cannot be regained.

Disease of the mucous membrane, and impaired action of its muscular coat, also results from disease of the central part of the

nervous system, and some of these cases are among the most distressing which the physician is ever called upon to treat. The affection begins perhaps in the nerve-cells of the cord itself. These gradually undergo change, and many cease to act, or the nerves arising from them may be pressed upon or degenerate in structure at some distance from their point of origin. Over these structural changes we can exert little influence by remedial agents, and as the disease proceeds, the state of the patient becomes more painful to witness.

These structural diseases of the cord are of the utmost interest, and their pathology has only very recently been studied. I beg to refer the reader to some most interesting and very complete cases by my friend, Mr. Lockhart Clarke, in the "*Archives of Medicine*," Vols. II. and III.

395. Of the Treatment of Cases in which Phosphatic Deposits occur.—When the condition is only temporary, small doses of dilute acids in a bitter infusion before meals, or the tincture of the sesquichloride of iron, will generally cause the urine to become healthy by improving the action of the stomach. Pepsin (§ 316) may also be given with advantage in some of these cases. Benzoic acid and Benzoate of ammonia have also been prescribed, and sulphate of zinc, extract of nux-vomica, are favourite remedies. If the intestinal canal be loaded and the patient have been living too well, as is not unfrequently the case, a little blue pill and compound colocynth pill will set the patient right.

Alkalies, as Dr. Owen Rees was the first to show, undoubtedly do good in some of these cases of phosphatic urine, probably by their action in promoting the normal chemical changes in the blood rather than by direct action upon the kidney or any part of the genito-urinary mucous membrane. Dr. Rees' explanation has been already referred to (§ 200).

When the phosphate in the urine has persisted for some time, and is accompanied with any symptoms referrible to probable affection of the cord, especially if the bladder be irritable, and there be nervous twitching of the muscles, with tingling or numbness of the skin in any part of the lower half of the body, or diminished control over the voluntary movements, acids and tonics, with small doses of opium, should be given. The practitioner will,

however, meet with many cases in which the symptoms would justify him in inferring disease of the cord, nevertheless get quite well as soon as the general health is improved. The practitioner before treating such cases must find out how the patient lives, and ascertain if he is suffering from mental anxiety, excitement, over-mental work, &c., and he must avoid giving the patient reason to suspect that he thinks he is suffering from any organic disease, for many of these patients are terribly nervous, and too prone to dwell upon every ache or pain they may have, and are foolish enough to refer to medical books, with the view of ascertaining its cause. The diagnosis in these cases should be very guarded, unless the symptoms clearly and positively indicate the real nature of the disease. The consideration of this extensive subject cannot be further pursued here, and I must refer the reader to treatises on diseases of the cord.

The treatment of disease of the bladder, in which the urine contains pus as well as phosphate, has been already referred to (§ 386). *See* also Chapter XVIII. on Calculi.

CHAPTER XVI.

Urine in Disease. IV. Of Granular and Crystalline Deposits, small in quantity.—*Uric Acid—Of the Crystalline Forms of Uric Acid—Tests for Uric Acid—Of the Clinical Importance of Uric Acid—On the Treatment of Cases in which Uric Acid is deposited from the Urine—Xanthine—Oxalate of Lime—Octohedral Crystals of Oxalate of Lime—Form and Composition of the Crystals—Dumb-bell Crystals of Oxalate of Lime—Of the formation of the Dumb-bell Crystals—Of the Conditions under which the Dumb-bell Crystals occur—Chemical Composition of the Dumb-bell Crystals—Deposits often associated with Oxalate of Lime—Of the Examination of Deposits of Oxalate of Lime in the Microscope, and of their Chemical Characters—Of Oxalate of Lime in a Clinical Point of View—Of the Treatment of Cases in which Oxalate of Lime is deposited from the Urine—Cystine—Analyses of Urine containing Cystine—Of Cystine clinically, and of the Treatment of Cases in which Deposits occur—Carbonate of Lime—Silica or Silicic Acid—Blood-corpuscles—Chemical Characters of Urine containing Blood—Of Blood in the Urine clinically—Of the Treatment of Hæmaturia—Circular Sporules closely resembling Blood-corpuscles — Cancer-cells — Tubercle-corpuscles — Spherical Cells containing Nuclei and Granular Matter—Small Organic Globules.*

IV.—Third Class of Urinary Deposits.

396. **Uric or Lithic Acid.**—Among the deposits which I have arranged in a third class, and which are characterised by their small bulk, by their crystalline or granular appearance, as well as by their

density, may be mentioned, in the first place, *uric* or *lithic* acid—a substance which has before been brought under notice as a constituent of healthy urine, and of which the chemical properties and general characters were then briefly referred to (§§ 135, 213). Uric acid forms a crystalline deposit, and perhaps is more frequently met with than any other form of urinary sediment, with the exception of the urates; and although there seems reason to believe that, as chemico-pathological investigation advances, we shall no longer regard the presence of this, or indeed of any other substance, in the urine, as evidence of the existence of a particular diathesis, its presence in many cases, especially when the deposit occurs very frequently and in considerable quantity, affords an indication that the chemical changes in the organism are more or less modified.

The *quantity* of uric acid in the urine depends, to a certain extent, on the activity of the skin; and, as a general rule, when there is profuse cutaneous perspiration, the amount of uric acid in the urine will be found to diminish. If, on the other hand, the function of the skin be in any way impaired, or perspiration be impeded by cold, a considerable increase in the quantity of uric acid will take place. Marcet found that the amount of uric acid diminished after severe perspiration; and Fourcroy noticed more uric acid in the urine of a man in winter than in summer. In this way may be explained the presence of the large quantity of uric acid in the urine of persons affected with acute dropsy, or dropsy after scarlatina; and it seems probable that the frequency with which these deposits are met with in the urine of persons affected with skin diseases (especially eczema and lepra) may be due simply to the impaired function of the skin. In increased muscular exertion, accompanied with imperfect respiratory action, uric acid occurs in abnormal quantity. It is present as a deposit in very many cases of chorea. It should, however, be borne in mind that uric acid is often dissolved in the urine as a urate at the time it is passed, but is afterwards precipitated, being perhaps separated from its combination with soda (urate of soda) by the process of acid fermentation.

397. Of the Crystalline Forms of Uric Acid.—In the great variety of crystalline forms which uric acid assumes, it is not surpassed by any other substance. Its true primitive form is not easily determined; but that in which it appears most constantly is

the rhombic, although in many instances this occurs with two of its angles rounded. From its salts, however, the acid may be separated in rhombic tablets, or in six-sided plates, somewhat resembling crystals of cystine, by the addition of acetic, nitric, or hydrochloric acid.

The form of the crystal is much affected by the strength of the acid which is added. This subject has been investigated by Dr. A. E. Sansom ("*Transactions of the Medical Society of King's College, London, Winter Session*, 1856-57," p. 128). The following are the results:—

Acid in small quantity . .	Crystals regular; mostly tables and squares; lozenges.
Acid in large quantity, added to a strong solution of urate of ammonia	Large and long tables, with very elongated lozenges.
Acid strong; amorphous urate itself used	Acicular prisms most frequent.

The various forms which the substance assumes in urine may often be traced, by intermediate stages, from one into the other; but the conditions which determine the changes have not yet been satisfactorily explained. Doubtless the length of time occupied in the formation of the crystal has much influence in determining its form; for not unfrequently one crystal is observed to acquire entirely different characters if it be allowed to remain for a longer period immersed in the urine. Some of the commonest forms met with are represented in Plate XI., Fig. 57, and Plate XX., Figs. 105, 106. The most important crystalline forms, besides the rhombic, are the rectangular quadrilateral prisms with terminal planes, and the dumb-bell crystal. All other forms appear to be some modification of these three. The dumb-bell form of crystals is occasionally met with in deposits; but it may often be readily obtained by the addition of an acid to urine. These crystals must not be mistaken for dumb-bells of oxalate of lime, from which they may be distinguished by their large size and darker colour, and by their being readily soluble in alkalies. Pure uric acid often crystallises in micaceous plates. Uric acid deposited in urine can generally be distinguished by its colour from other crystalline deposits, although two or three instances have come under my notice in which the crystals were found to be perfectly colourless. Various forms of

uric acid are represented in Plate XI., Fig. 57, also in Plate XX., Figs. 105, 106; *see* also "*Illustrations*," Plates IV., V., VI., VII. A very curious form of crystal is referred to and figured in Plate XIX., Figs. 3 and 4, Vol. i. of the "*Archives of Medicine*."

Uric acid is sometimes deposited very rapidly, when it forms a thin glistening film, in which no indication of crystalline form can be detected. A film of this kind was brought to me some time since by Dr. Chambers. After the lapse of a day or two, well marked crystals made their appearance. Some of these films are composed of layers of small crystals, closely matted together. After the lapse of a short time, the larger crystals grow, while the smaller ones disappear; so that at length a number of large well-defined crystals are produced.

A deposit of uric acid sometimes resembles amorphous urate, and even under very high powers of the microscope nothing but minute granules can be detected, even for some hours after the urine has been passed. This deposit is not soluble in boiling water, and in the course of from 24 to 48 hours the granules will be found to have increased considerably in size, while many exhibit well-defined crystalline form.

398. Tests for Uric Acid.—When we are in doubt as to the nature of a deposit suspected to consist of uric acid, we may examine it as follows. If it consist of uric acid, it will be insoluble in hot water, but soluble in alkalies, potash, soda, and ammonia.

1. A portion of the deposit is to be dissolved in a drop of potash. The alkaline solution is then to be treated with excess of acetic acid. After the lapse of a few hours, crystals of uric acid will be formed, which must be subjected to microscopic examination.

2. A sediment, suspected to be composed of uric acid or a urate may be placed upon a glass slide, and treated with a drop of strong nitric acid. After evaporation to dryness at a gentle heat, the slide is to be exposed to the vapour of ammonia, or a drop of ammonia may be added to the dry residue. A beautiful violet colour, owing to the formation of murexide, proves the presence of uric acid or a urate.

399. Of the Clinical Importance of Uric Acid.—This substance exists in the blood, in combination with a base, as an alkaline or earthy urate, which is comparatively soluble. The soluble urate

may be decomposed; 1, when it arrives in the uriniferous tubes; 2, subsequently, when the urine reaches the bladder; or, 3, as more commonly happens, the acid may not be set free until some time after the urine has been passed.

In the first case, the acid may accumulate and block up the tubes, or perhaps form a small concretion; but, as I shall show in the next chapter, oxalate of lime very frequently forms the real nucleus of these uric acid calculi which are so common. In the second case, if a small concretion of any kind exist in the bladder, uric acid is deposited around it, and a uric acid calculus becomes rapidly formed. The deposition of uric acid after the urine has been passed is often merely accidental, and depends upon the decomposition of the urates by a process of acid fermentation, which has been fully investigated by Scherer. The acid crystallises sometimes very soon after the urine has been voided, sometimes not for some days afterwards. I have before alluded to the importance of not regarding the *deposition* of uric acid crystals as in all cases depending upon *excess* of the acid in the urine. There may actually be less uric acid than is present in health, although it may be deposited entirely in an insoluble form.

I may state generally, that we are likely to meet with this deposit in cases where a liberal meat diet is indulged in by those who take very little exercise; and in the urine of people who lead very sedentary lives, it is not uncommon. In various gouty affections it is very frequently observed. In diseases of the liver, it is especially common; and temporary congestion of that organ is very frequently associated with the presence of much uric acid in the urine. In chronic diseases of the respiratory organs, we often meet with uric acid and urates in the urine. It is common in emphysema of the lung, and in chronic bronchitis. In pneumonia and rheumatic fever, it is often found. It is seldom absent from the urine in chorea, and very often exists in various forms of skin-disease, and in cases of acute inflammation of the kidney. It is occasionally met with in diabetes.

There are many cases in which the tendency to deposits of uric acid is not very easily explained. Some children are very liable to suffer from uric acid deposits, and their appearance is accompanied by frequent desire to pass urine. In cases where the deposit is very frequent it is necessary to interfere.

I have seen instances of uric acid deposits, occurring in adults in which ordinary remedies appeared to exert no effect. The urine of a patient suffering from emphysema of the lung always contained a large quantity; and it appeared while she was taking considerable doses of alkalies, and also when she was put upon mineral acids. The connection between deposits of uric acid and gout has been referred to in page 163.

400. On the Treatment of Cases in which Uric Acid is Deposited in the Urine.—Occasionally we meet with patients who appear generally in good health, but who complain of getting thin, although they live well, in many instances perhaps too well, and suffer from an almost constant deposition of uric acid. It is very difficult to explain this symptom in every case in which it occurs; but I feel sure that many of these persons overtax their digestive organs, and are in the habit of eating too much. They think that the only way to gain flesh is to consume a large quantity of food; and, in consequence of too much work being thrown upon their digestive organs, especially the liver, assimilation is not properly carried on, and a quantity of material is formed which is unfitted for the wants of the organism, and is perhaps got rid of in the state of urea, uric acid, and urates. By cutting off a certain part of the supply, their anxiety as to the gravel is soon relieved, and at the same time, to their surprise, they gain strength and increase in weight.

I have already alluded to the great objection of employing the term "uric acid diathesis" (page 141), and have referred in § 214 to the general principles which should guide us in the treatment of cases in which an excess of uric acid is eliminated in the urine. The occasional deposition of uric acid crystals from the urine requires no medical treatment, or at most a dose of bicarbonate of potash after meals or the last thing at night. In some cases in which these deposits are frequent, and in people of a gouty tendency, small doses of hydrochloric acid with pepsin, before meals, and twenty grains of bicarbonate of potash, in half a tumbler of water, after meals, is a plan which answers admirably.

401. Xanthine ($C_{10}H_4N_4O$) or Uric or Xanthine Oxide is a substance closely resembling uric acid in many of its characters. It is very rarely met with in urine. It was described first by Marcet, and has since been detected in the blood, and also in the spleen,

muscles, liver, and brain. It is rarely met with in the crystalline form, but Bence Jones reports the case of a boy, aged 9½ years, in whose urine xanthine crystallised in lozenge-shaped crystals, which were first mistaken for uric acid. The deposit disappeared on boiling the urine, and was soluble in water, nitric, and hydrochloric acids, and in alkalies (quoted by Hassall). Douglas Maclagan also reports a case in which xanthine occurred in a urinary deposit. Xanthine is probably a common constituent of urine, but exists in very small quantity. A rare form of calculus is entirely composed of it. Xanthine is stated by Dr. John Davy to be the principal constituent of the urine of spiders and scorpions.

Oxalate of Lime.

The next substance which is to be noticed is oxalate of lime, which was first shown to be a common urinary deposit by Dr. Golding Bird. It is seldom deposited in quantity sufficient to be recognised by the unaided eye, or to be subjected to chemical examination.

402. Octohedral Crystals of Oxalate of Lime.—This salt crystallises in well-defined octohedra, having one axis much shorter than the two others. The crystals vary much in size, and two or three forms have been described by authors. In the cases I have met with, the different appearances of the crystals were due to the position in which they were viewed, as may be readily proved if a little glass model be constructed. The flattened octohedron is obviously the most common appearance, because the crystal lies most easily on one of its faces. If, however, it be turned with one of the long axes directed towards the observer, while the other is held upright, the short axis will necessarily be transverse, and the crystal will appear as a long and very acute octohedron (Plate XXI., Fig. 107, *a*). If now one of the lines formed by the meeting of two opposite faces be turned towards the observer, there will still be the appearance of an acute octohedron; but it will be less acute than before, and no transverse line in the centre can be made out. Upon keeping the same line towards the eye, and by carefully turning the crystal, so that the two opposite faces are made quite parallel to each other, the appearance as of a long-shaped four-sided crystal will be produced. The different appearances produced by viewing the same

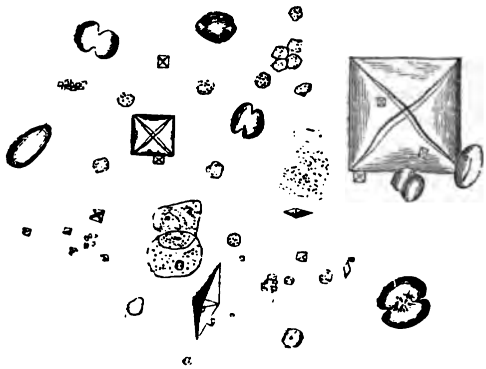
crystal in different positions are represented in the "*Illustrations*," Plate XI., Fig. 1, *a, b, c, d, e.* Crystals in all these different positions, appearing as different forms, are commonly met with in the examination of urinary deposits. In Plate XXI., Figs. 107, 108, are represented octohedra in various positions, dumb-bells, and circular and oval crystals of oxalate of lime, with two cells of bladder epithelium, deposited from the urine of a patient suffering from a tense state of the skin of the wrists and arms, a condition which is sometimes termed "hide-bound."

Many observers have figured these crystals incorrectly. Dr. Golding Bird considered that they belonged to the cubic system. Dr. Prout, however, has given a figure of oxalate of lime which clearly shows that he was aware of the exact form of the crystal. Prismatic crystals of oxalic of lime occur in some plants, and they have been observed by Beneke in urine. I found that some preparations of ordinary oxalate of lime, which had been kept for some years in preservative fluid, underwent a change in form, and were at length entirely replaced by beautiful prisms. Plate XXI., Fig. 109, represents a rare form of crystal. The extremities resemble the two faces of an ordinary octohedron, but they are separated by an intervening quadrilateral prismatic portion.

Oxalate of lime may be obtained in its usual octohedral form from its solution in hydrochloric acid; and Neubauer states that from a solution in phosphoric acid, crystals may be obtained by neutralising the acid by soda or potash.

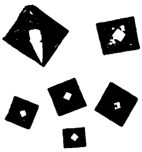
Dr. Thudichum has carefully examined the form of crystals of oxalate of lime obtained in different ways, and he brings all the different forms he has observed under the following heads: *quadratic octohedron, crossed octohedra, quadratic octohedron and prism* combined; *crossed prisms; triple twins,* with *tropia;* modifications of *crossed octohedra;* contortions and anomalies, including dumb-bells. He also shows, contrary to previous statements, that the salt actually possesses a polarising power, as should be the case if it belongs to the quadratic system. This is, however, difficult to demonstrate, and can be only brought out fully by reflecting a ray of the sun through the crystal, which accounts for the fact having escaped observation. I had long ago examined crystals by the polariscope which had been mounted in Canada balsam, and had noticed that they were often slightly illuminated when the field was

Fig. 107



§ 402 × 215

Fig. 108.



§402

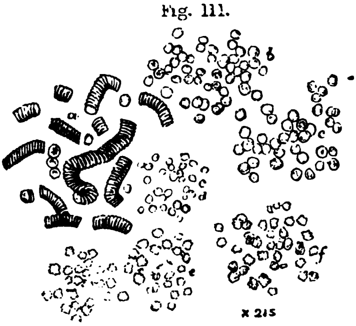
Fig. 109.

§ 402

Fig. 110.

§ 403 × 215

Fig. 111.



§ 416

Fig. 112.

§ 403

Fig. 113.

§ 403

To face page 344.

dark. Although I had figured the form of the crystals correctly, I must confess that I was too ready to agree with the statements made by others as to the system to which this crystal belonged; nor was I sufficiently acquainted with crystallography to discuss this question fully. In this matter Dr. Thudichum has corrected me; and, after a re-examination of the question, it is only right that I should state that the octohedra, mounted in Canada balsam, do polarise even with a good artificial light; and therefore no argument in favour of the dumb-bell crystals being composed of oxalurate, and not of oxalate of lime, can be based on the statement that the octohedra do not polarise.

403. **Dumb-bell Crystals of Oxalate of Lime.**—Oxalate of lime, however, occurs more rarely certainly, but still not uncommonly, in another very interesting form, which was first pointed out by Dr. Golding Bird. From their resemblance to dumb-bells, these bodies are known as the dumb-bell crystals of oxalate of lime. Dr. Golding Bird thought that they were composed of oxalurate, and not of oxalate of lime; but the following points, in addition to what has just been stated, render this very improbable.

1. Octohedra, in all the cases I have observed, were deposited from the specimen of urine in which the dumb-bells were found, and invariably precede and follow the appearance of the dumb-bell crystals.

2. Minute calculi are often composed of dumb-bells, as may be shown by microscopical examination; and these calculi have been proved by analysis to consist of oxalate of lime.

Organic matter exists in every part of the dumb-bell. By the prolonged action of acetic acid the crystalline material is dissolved out, leaving this organic matter. Mr. Rainey has shown that the presence of viscid organic matter prevents crystalline substances from assuming their usual form, and causes the crystalline material to be deposited in the sperical or dumb-bell form. Now when the crystalline matter is dissolved out the organic basis remains, and its sharp outline looks like that of a cell-wall (Plate XXI., Fig. 112). The appearance of a cell-wall may be observed, if the earthy salt from the spherical and dumb-bell crystals of carbonate of lime in horses' urine be dissolved out by an acid. The same point may be demonstrated upon a larger scale by treating the small phosphatic calculi, sometimes found in the kidney in considerable number or prostatic calculi, with dilute acid. In all these cases the outline of the

transparent matrix gives the idea of a hollow transparent membrane or cell. A spherical mass of jelly or any other transparent solid substance would exhibit a similar well-defined outline. This sharp line has been accepted as evidence of a cell-wall in innumerable cases where no such structure really exists.

Some persons have stated that these dumb-bell crystals of oxalate of lime were composed of uric acid—a mistake for which it is very difficult to account, since, in their optical characters and chemical properties, they widely differ. The uric acid dumb-bell is instantly dissolved by dilute potash, and, by the addition of excess of acetic acid, rhombic crystals will be thrown down; while the dumb-bell of oxalate of lime is insoluble in a strong boiling solution of potash.

Besides the dumb-bell, it is common to meet with a number of closely allied forms, among which may be mentioned circular and oval crystals. ("*Illustrations*," Plate XI., Fig. 2, *a, b, c, d, e, f.*) In several of the cases which have fallen under my notice, the true and perfectly shaped dumb-bell was preceded by circular and oval crystals; and these also again appeared after true dumb-bells could no longer be detected in the urine. These crystals often disappear the day after multitudes have been found; and generally they are only noticed for a few consecutive days—a circumstance which may perhaps account for the comparatively few instances in which these crystals have been noticed. Two or three oval crystals are seen in Plate XXI., Fig. 107.

404. Of the Formation of the Dumb-bell Crystals.—It is well known that the octohedra of oxalate of lime are commonly deposited in the urine after it has left the organism; and if urine which contains very minute octohedra be allowed to stand for a few days, these may often be observed to increase in size, until at length they became very large crystals, while at the same time a number of new ones are developed. On the other hand, dumb-bell crystals are present in the urine when it is passed, and they do not increase in size or number if allowed to remain in it. These dumb-bell crystals are formed in the renal tubes. I have found them entangled in casts in the urine of a cholera patient passed after eighteen hours complete suppression during the stage of collapse. The specimen of urine in which these casts were found was very acid, of a dark colour,

and specific gravity 1024. The urine contained no albumen. The following report was made at the time of examination. Deposit very slight, consisting of transparent, smooth, and hyaloid casts, for the most part homogeneous, but in a very few of them a small quantity of granular matter was observed. In others, dumb-bell, oval and globular crystals of oxalate of lime were noticed. The dumb-bell crystals were seen only in the casts, but many octohedra were observed in the surrounding fluid. ("*Illustrations*," Plate XXII., Fig. 1.)

I have seen many times a number of dumb-bells impacted in the tubes of the kidney, especially in the pyramids. Indeed, if thin sections of this portion of human kidneys be made, these dumb-bell crystals will be observed not unfrequently. Often several may be seen in the wide portion of the tube, just before it opens upon the surface of the mamilla.

It is probable that were *octohedral* crystals appear to be in casts, they are really deposited upon the surface or in the substance of the cast, some time after the urine has left the bladder.

405. Of the Conditions under which Dumb-bell Crystals occur.—I have met with a great many specimens of urine containing dumb-bells, but have been unable to associate the appearance of these crystals with any particular morbid condition. It may be interesting to refer to a few of the cases which occurred in the hospital some years ago. During six months, I met with ten or eleven cases, in which these peculiar crystals were present, out of about four hundred cases in which the urinary deposit was examined; but I have not observed that the urine containing them possesses any characters by which we might be led to suspect their presence, before resorting to microscopical examination; and, from my own observations, it does not appear that the dumb-bells are connected with any peculiar form of disease, or with any particular diathesis. They occur usually mixed with the ordinary octohedra of the oxalate, but I have found them alone; frequently they are found accompanied with urate of ammonia and crystals of uric acid, and often with both. Out of ten cases in which they were present, eight were men, and the remaining two were women, above the age of 21. Of these ten cases, nine occurred between the months of September and January, and one in April; but this may be accounted for by the fact, that during the winter I have always made a much greater number of

microscopical examinations than during the summer months. It may prove interesting to give a list of the cases in which these dumb-bell crystals, or crystals allied to them in form, occurred. They were present in—

One case of chorea.

Two cases of cholera.

One case of chronic rheumatism.

One case of contraction of the skin of the neck and upper extremities, the condition to which the term "hide-bound" has been applied.

One case of boils, occurring in various parts of the body.

One case of paraplegia, depending upon diseased vertebræ.

One case of attempted poisoning by taking half an ounce of oxalic acid.

One case of eczema.

One case of epilepsy.

Out of these ten cases, in which the dumb-bell forms of crystal were present, it will be observed that only two instances occurred in which they were found in the urine of patients afflicted with a similar disorder, and it is somewhat curious that these should be cases of cholera. The other cases differ so entirely in nature from each other, that one cannot conclude that this curious form of crystal is in any way dependent upon the nature of the malady, but we are rather led to the conclusion that these crystals arise from certain conditions unconnected with any particular disease. The dumb-bell crystals often occur in the urine of persons not suffering from any special disorder at all, who consider themselves in good health; but generally there is languor and loss of appetite, with uneasiness after eating, and the individual, without being able to give an account of any particular ailment, complains of not being quite well. Dumb-bells often occur in cases where little exercise is taken, with a full diet, and too little water. The concentration of the fluids, and imperfect oxidation, will fully account for the formation of these crystals in cases of cholera; and it is probable that similar conditions are present to a less extent, and owing to a different cause, in other cases in which dumb-bell crystals have been detected.

Sometimes several dumb-bells adhere together, forming an irregularly-shaped mass, which gradually becomes smooth by the deposition of the same material in the interstices, until a small, nearly spherical

or oval, mass is formed. (*See* Fig. 125, Plate XXIII.) In other cases, it would appear that one or two crystals grow at the expense of the rest, and a perfectly uniform oval crystal, composed, of course, of numerous acicular crystals, radiating from a common centre, results (Fig. 124). Thus the dumb-bell crystal becomes the nucleus of a small calculus, and it is easy to see how this may increase in size by the deposition of new matter externally—at first, while it remains in the straight portion of the uriniferous tube, or in that system of irregularly-shaped cavities at the apex of the mamilla, formed by the convergence of several of the large tubes; then in the pelvis of the kidney or ureter; and, lastly, in the bladder itself.

406. Chemical Composition of the Dumb-bell Crystals.—The chemical composition of these crystals has long been a matter of dispute among chemists, but it may now be regarded as nearly certain that they consist of oxalate of lime; for since it has been shown that the dumb-bell may gradually grow into a small calculus, and that the latter is composed of oxalate of lime, we are certainly justified in inferring that the dumb-bell or *microscopic* calculus has the same chemical composition. No difference in chemical character, refractive power, or in the action of polarised light, can be detected between the minute dumb-bell or oval crystals, and the aggregations of dumb-bells which are from time to time met with forming microscopic calculi. There cannot, in fact, be the slightest doubt of their being the same substance in different stages of deposition. Nor can there be any question of the latter being, in their turn, an early condition of the small renal oxalate of lime calculi. In very many instances the nucleus of a uric acid renal calculus consists of oxalate of lime.

407. Deposits associated with Oxalate of Lime.—Oxalate of lime is often found associated with other deposits, particularly with urate of soda, in which case the minute crystals are easily passed over amidst the amorphous deposit. The peculiar form of crystals of earthy phosphate described in § 392, are usually found in urine from which oxalate of lime is also deposited.

Crystals of oxalate of lime are so minute that, without care, they may be readily passed over in a microscopical examination; and very frequently the only appearance observed in the microscope is the presence of clusters composed of minute cubical or square-shaped crystals, which appear almost opaque. Indeed, such clusters of

oxalate of lime crystals may be easily mistaken for urate of soda, from which, however, they may be readily distinguished by the fact of their not being dissolved upon warming the slide, and by their insolubility in potash and acetic acid. Crystals of this character are often found adhering closely to hairs and other substances. Deposits of oxalate of lime and uric acid are represented in the "*Illustrations*," Plate XXI., Figs. 5 and 6; and of oxalate of lime and phosphate, Plate XXII., Figs. 5 and 6.

408. Of the Examination of Deposits of Oxalate of Lime by the Microscope, and of their Chemical Characters.—The larger crystals are readily recognised by their microscopical characters; and the only crystals I have known mistaken for them are crystals of triple phosphate, as I mentioned when speaking of the phosphatic deposits. If, however, there be any difficulty, a drop of acetic acid will soon set the question of the composition of the crystal at rest.

Oxalate of lime deposits seldom sink to the bottom of the vessel in which the urine is placed, but seem to be buoyed up by the slight mucus deposit present. When, therefore, a drop of urine is taken for examination, there is no necessity for taking it from the very bottom of the vessel, the stratum of fluid slightly above this point being often richer in crystals.

Oxalate of lime seldom occurs in urine in sufficient quantity for chemical examination. If oxalate of lime be burnt in a platinum capsule, and the carbonised residue be exposed for some time to the dull red heat of a spirit-lamp or other flame, a white deposit will remain, which will be found to be insoluble in water, but it will be dissolved in acetic acid with copious effervescence, showing that, by the process of combustion, the oxalate has been converted into carbonate. If, however, the carbonate has been exposed to a bright red heat, there will be danger of its partial or complete conversion into lime, in which latter case no effervescence will occur upon the addition of an acid. In the acetic acid solution, the presence of lime may be detected upon the addition of oxalate of ammonia, oxalate of lime being quite insoluble in acetic acid.

409. Of Oxalate of Lime in a Clinical Point of View.—There is still much difference of opinion among practitioners as to the clinical importance of oxalate of lime. There can be no doubt that, in the majority of instances, the crystals form after the urine has left

the bladder; and there is good reason for believing that the oxalic acid is often produced by decomposition of the urates after the urine has been passed. The experiments of Dr. Aldridge, of Dublin, show that uric acid and urates are easily decomposed into oxalic acid and oxalates. Dr. Owen Rees entertains the opinion that this substance is derived from the urates, and that, when present in the urine, it indicates the existence of urates in the blood. Oxalate is often deposited in the urine of gouty cases, and it is certainly very often found among urate deposits. Although there are certain conditions of the system in which both oxalates and urates are very common, both deposits may be present—indeed very commonly are present—in the urine of healthy persons. Hence it is obvious, that the presence of such deposits is no indication of the existence of any particular diathesis. The fact seems to be rather, that, in what is termed the "*oxalic diathesis*," among other symptoms, oxalate of lime is present in the urine; but this is not the most important symptom, and the practitioner cannot make a greater mistake than to direct attention, in such a case, to the urinary deposit alone, or consider this the most important indication for treatment. In the same case, at one period, we may find uric acid and urates; after a time, these mixed with oxalates; and, lastly, they may give place to a deposit of oxalate alone.

Wöhler and Frerichs injected uric acid into the blood of a dog, and found oxalate of lime in the urine. Oxalate of lime passes through the alimentary canal unchanged; but oxalic acid is in part excreted in the urine, while part is decomposed in the system. Bucheim and Piotrowsky have shown that small repeated doses of oxalic acid (fifteen grains every hour for six hours) are not poisonous. Not more than 12 per cent. of that taken by the mouth appears in the urine. I have detected oxalate of lime in the urine of several persons who have attempted to poison themselves with oxalic acid.

Oxalate of lime is, however, not *always* formed *after* the urine has reached the bladder. I have shown that there is very strong evidence of its deposition in the tubes of the kidney in certain cases, in the form of dumb-bell crystals; and it must therefore have been formed at the time of the separation of the urine from the blood, if it did not exist in solution in the blood itself.

It appears, then, that oxalate of lime may be excreted in the

urine when oxalic acid or oxalates are taken in the food. It may be formed in the organism itself; and it may be produced by the decomposition of uric acid and urates after the urine has left the bladder.

Beneke has shown that the earthy phosphates and oxalates increase in direct proportion to each other. The nutrition of the tissues generally would be impaired under the same circumstances; and a larger amount of earthy phosphate would pass off in the urine dissolved by the oxalic acid. ("*Archiv. des Vereins*," Band I., Heft. 3.)

It must be borne in mind that oxalate of lime is often discovered in almost opposite conditions. Thus it is sometimes present in poor broken down subjects, and it is found in the urine of well-to-do country gentlemen. It will appear when we live too well and take too little exercise. It is common in chronic pulmonary affections, as bronchitis; and it is often observed in old cases of emphysema. It is common enough in dyspeptics, and is usually met with in cases of jaundice. In various forms of general debility, in cases of over-fatigue, and in men who have overworked their minds, it is perhaps the commonest urinary deposit. Lastly, I have found it many times, and in very large quantity, in the urine of men who appear in all other respects in perfect health.

410. Of the Treatment of Cases in which Oxalate of Lime is deposited from the Urine.—The remarks made in the last section render it almost unnecessary to devote a special section to the subject of treatment. As a general rule, it will be found that anything which improves the general health and promotes oxidation will diminish the tendency to deposit oxalate of lime. Cold bathing, exercise, attention to diet, and the mineral acids, bitter tonics, and iron, are usually prescribed with advantage. I feel that by many writers too much has been made of the indications for treatment afforded by many of these urinary salts. Many cases of what has been called the 'oxalic acid diathesis,' because the urine contains octohedra of oxalate of lime, may in truth be treated by the practitioner just as successfully without taking into consideration the presence of the oxalate as by laying stress upon this fact. The patient will probably, in either case, be treated with tonic infusions and dilute acids (nitric or hydrochloric, or both), with a gentle

purgative now and then. Pepsin may also be given. The diet should be simple, and small quantities of whisky or brandy in seltzer or Vichy water may do good.

Although the octohedra of oxalate of lime afford no special indication for treatment, the *dumb-bells*, on the other hand, certainly do so; for these dumb-bells may form the nuclei of renal calculi. In cases, therefore, in which they are found, it is well to promote their expulsion from the kidney, and endeavour to prevent the formation of more by giving mild diuretics, with plenty of fluid. Two or three glasses of Vichy water daily for two or three days will generally wash these crystals out of the tubes and prevent the formation of others.

411. Cystine ($C_4H_7NS_2O_6$) occurs occasionally as a crystalline sediment in urine, and also enters into the composition of a rare form of calculus which has been termed the cystine calculus. Cystine was formerly spoken of under the name of cystic oxide, and the same term was applied to the calculus.

Cystine forms a whitish deposit, which is found, upon microscopical examination, to consist of characteristic *six-sided plates* (Plate XIV., Fig. 72), which may be distinguished from uric acid crystals of the same form by dissolving a portion of the deposit in ammonia. Upon the spontaneous evaporation of this ammoniacal solution, the cystine is again deposited unchanged in its hexagonal crystals; while uric acid would have been converted into urate of ammonia, which, on evaporation, would have remained as an amorphous residue. Ammonia, it appears, merely dissolves the cystine, and does not enter into combination with it. Cystine is insoluble in boiling water, in strong acetic acid, and also in very weak hydrochloric acid; but it is readily dissolved by oxalic, and by the strong mineral acids. The most remarkable property of this substance is, that it contains as much as 26 per cent. of sulphur—a character in which it resembles taurine. Potash, like ammonia, readily dissolves cystine; but it is insoluble in carbonate of ammonia. The presence of sulphur in cystine may be proved by heating the substance in an alkaline solution of oxide of lead, when a black precipitate of sulphuret of lead occurs. This test cannot be regarded as characteristic of cystine, because all animal matters containing sulphur exhibit a similar reaction. Urine containing cystine is said to smell very much like sweet briar.

Dr. Golding Bird has observed that calculi composed of this substance undergo a change of colour by long keeping. From pale yellow or fawn coloured, they have been found to assume a greenish grey, and sometimes a fine greenish blue tint. Crystals of cystine may be obtained from a calculus composed of this substance by dissolving a portion in a solution of potash, and adding excess of acetic acid to the alkaline solution, when the cystine will be deposited in six-sided plates. Virchow and Clöetta have proved that cystine is sometimes found in the liver; while taurine as well as cystine have been detected in the urine.

Of *the conditions of system* which give rise to the elimination of this substance by the kidneys, little is at present known. In the majority of cases in which it has been found, the general health and nutrition of the patient have been bad. Dr. Johnson found cystine once in the urine of a prisoner, and it is from time to time met with in the urine of ill-nourished persons.

When examining the urine of the insane for Dr. Sutherland ("*Trans. Med. Chir. Soc.*," Vol. XXXVIII., 1855, p. 26), I was surprised at the number of specimens which emitted large quantities of sulphuretted hydrogen after standing a few days. It is not improbable that the sulphur resulted from the decomposition of cystine or some allied substance.

412. Analysis of Urine containing Cystine.—The notes of the following interesting case were kindly furnished by Dr. Milner Barry of Tunbridge Wells, who also procured for me some specimens of the urine for analysis.

Case.—"Mr. A., aged 23, dark complexion, well built and well nourished, of active habits, assiduously engaged in the duties of a laborious profession, suffers occasionally from sick head-ache, but is otherwise in the enjoyment of excellent health. The presence of cystine was ascertained microscopically at the beginning of October, 1857; but, as deposits supposed to be urates had often been previously noticed, the probability is that the cystine had been excreted in the urine for a long time. It seems now never to be absent from the urine. Debilitating agencies, and whatever promotes the metamorphosis of tissue, intellectual exertion, active bodily exercise, mental anxiety, and smoking, appear to cause an increase in the amount of cystine. You will observe the much larger relative

proportion of the ingredient in the morning urine than in that passed in the evening a few hours after a meal. There is no lumbar pain, and no irritability of the bladder." ("*Archives of Medicine,*" Vol I.)

The first specimen of urine was received in October, 1857. It was of the natural colour, of acid reaction, and had a smell not unlike that of sweet briar. Specific gravity, 1028.

Analysis 67.

			In 100 grs. of solid matter.
	Water	937·60	
	Solid Matter	62·40	
	Urea	32·80	51·28
	Uric acid	·50	·80
	Extractive matter	12·90	20·67
Fixed salts, 16·00	Sulphuric acid	1·70	2·72
	Chloride of sodium	12·00	19·23
	Earthy phosphates	1·00	1·602
	Alkaline phosphates	2·50	4·00

The next specimens were received on January 28th, 1858. No. 68 was passed on the morning of the 27th, at eight o'clock (before breakfast). Its specific gravity was 1034.

Analysis 68.

			In 100 grs. of solid matter.
	Water	916·00	
	Solid matter	84·00	
	Cystine	·906	1·08
	Urea	49·00	58·33
	Extractives	16·94	19·52
Fixed salts, 17·6*	Chloride of sodium	9·30	11·07
	Sulphuric acid	4·50	5·35
	Earthy phosphates	·60	·71
	Alkaline phosphates	4·20	5·00

No. 69 was passed at 9 P.M. on the 26th, three hours after dinner. Specific gravity, 1027.

* In these analyses the fixed salts were estimated by incineration, while the sulphuric acid, phosphoric acid, and chloride of sodium, were estimated volumetrically. The slight discrepancy in the numbers arises partly from the volatilisation of some of the saline constituents during incineration, and partly from slight errors in the analyses, unavoidable when only small quantities are operated on.

Analysis 69.

			In 100 grs. of solid matter.
	Water	949·30	
	Solid matter	50·70	
	Cystine	Too little to estimate.	
	Urea	28·40	56·01
	Extractives	1·30	2·76
Fixed salts, 19·6	Chloride of sodium	11·20	22·09
	Sulphuric acid	1·90	3·74
	Earthy phosphates	·60	1·18
	Alkaline phosphates	2·30	4·53

In these analyses, it is interesting to notice that the sulphuric acid is by no means deficient; indeed, in the second, the amount present is considerably above the average quantity met with in healthy urine. The proportion of cystine present, although it occupied a considerable bulk, was really very small; so that the opinion commonly entertained with reference to cystine being a compound in which the sulphur is removed from the organism in an unoxidised state, in consequence of the oxidising processes being in a low condition, will not explain its formation in the present instance, as the analyses prove that a much larger quantity of sulphur passed off as sulphuric acid than in a state of combination in the form of cystine. It is interesting to notice the large proportion of sulphuric acid present when the cystine existed in sufficient amount to be determined quantitatively.

413. Of Cystine Clinically, and of the Treatment of Cases in which Deposits occur.—Cystine has been met with in several different conditions of the system. In most of the recorded cases the patients have, however, been in a low weak state of health. Little is known with reference to the origin of this substance. It has been supposed to result from hepatic derangement, and Scherer and Virchow have detected cystine in the liver in disease. It is curious that cystine deposits occur in families, and even appear to be hereditary. Dr. Golding Bird speaks of an instance of its occurrence in three successive generations. As regards treatment I have nothing to add to the remarks made by Dr. Prout and Dr. Golding Bird. It is important to attend to the general health, and in several cases iron and the dilute mineral acids seem to have been of use.

414. **Carbonate of Lime** is said to occur occasionally in the crystalline form in human urine; its microscopical characters are somewhat similar to those of the carbonate of lime which is met with in the urine of horses and other herbivora; but the crystalline spherules are smaller and more delicate. From the drawings given, it would seem that the slender crystals of which the globular mass is composed are not arranged so compactly together as in the case of the salt so common in horses' urine. In highly alkaline urine, in which the alkalescence is caused by carbonate of ammonia set free by decomposition of urea, carbonate of lime occurs in small quantity, but in an amorphous form. This is the only form in which I have yet seen carbonate of lime in human urine. Carbonate of lime may be recognised by the effervescence produced upon the addition of a drop of acetic acid to the deposit suspected to contain it, care being taken that the sediment be well washed with distilled water before adding the acid, in order to remove any soluble carbonate that may be present.

Urinary calculi containing carbonate of lime have been met with, but they are not common. Mr. Hitchings, of Oxford, has removed two or three, which are deposited in the Oxford Museum.

Chalk or marble is occasionally added to urine, for the purpose of deceiving us. The presence of these substances is easily recognised by the action of acid, and by their being insoluble in water.

415. **Silica, or Silicic Acid (SiO_3)—Sand.**—It is asserted that silica sometimes forms a constituent of calculi. Berzelius long ago showed its presence in minute quantity in the ash of human urine; but it has never been met with as a deposit in this secretion, unless placed there in the form of sand, for the purpose of imposing upon us. I have received the urine of a hysterical girl for examination, containing nearly a fourth of its bulk of common house-sand. In this quantity we could hardly fail to detect its composition; but the presence of a few grains might possibly give rise to some little difficulty, when they were found in urine. Their nature, however, would be determined by treating them with boiling nitric acid, in which they are quite insoluble. Under the microscope, they appear as crystalline particles of a very irregular form.

416. **Blood-corpuscles** usually form a red or brownish-red gran-

ular deposit, which sinks to the bottom of the vessel. A few corpuscles are diffused through the urine. If the urine be perfectly neutral, or slightly alkaline in its reaction, the colour of the globules will be bright red; while, in those instances in which the reaction is decidedly acid, the globules will be found of a brown colour, imparting to the supernatant fluid a "smoky" hue. When the urine has a decidedly "*smoky appearance*," it generally happens that the blood is derived from the kidney; while, in the majority of cases in which it retains its florid colour, it comes from the bladder, prostrate, or urethra. Although the blood comes from the kidney, it will exhibit its ordinary florid red colour if the urine be alkaline. If blood-globules remain long in urine, they become much altered in form, the outline appearing irregular and ragged, and the surface granular. Not unfrequently the blood-corpuscles appear swollen and very much enlarged. These changes, no doubt, are chiefly dependent upon physical causes alone. The character of blood-corpuscles are represented in Plate XXI., Fig. 3, *a*, *b*, *c*, taken from the living body; *d*, *e*, *f*, from the urine; *d*, corpuscles smaller than natural; at *e*, their circumference serrate and ragged; and at *f*, a somewhat similar appearance is shown.

417. Chemical Characters of Urine containing Blood.—Urine containing blood-corpuscles must also contain serum; but the quantity of this fluid is in many cases very small, although numerous blood-corpuscles are to be discovered by microscopical examination. If there be much blood, the albumen of the serum is readily detected by the ordinary reagents.

418. Of Blood in the Urine clinically.—Blood in the urine may be derived from any part of the genito-urinary mucous membrane. In the female, it often escapes from the vessels of the uterus or vagina. It is, of course, always met with in the urine of the female at the catamenial periods. (*See* Plate XXII., Fig. 117.)

Blood may come from the kidney, in consequence of recent inflammation or old-standing disease leading to congestion and subsequent rupture of the vessels of the Malpighian body, or its escape may depend upon that peculiar condition of system in which there is a tendency to capillary hæmorrhage in all parts of the body.

When blood-corpuscles are found entangled in casts, we may feel certain that they come from the cortical part or secreting structure of the kidney. In these cases, the urine is generally acid and exhibits the well-known 'smoky' appearance which depends upon the action of the acid of the urine upon the colouring matter of the blood.

In cases in which, from various symptoms, we are led to suspect the existence of chronic kidney-disease, it is a favourable sign if the albumen is not detected after we fail, upon microscopical examination, to find blood-corpuscles. If the albumen, however, continues to be passed, we may feel certain that it was not solely derived from the serum which escaped through the ruptured capillary vessels with the corpuscles, but is to be attributed to chronic renal disease.

Hæmaturia may depend upon a calculus being impacted in the kidney, in which case it occurs perhaps for a day or two, and then ceases recurring after some days, or upon a calculus in the bladder. The existence of fungus of the kidney or bladder is almost invariably accompanied by hæmorrhage, which is sometimes very violent and exhausts the patient. The escape of blood may also be due to disease of the bladder or prostate.

Simple hæmorrhage, not dependent upon organic disease, sometimes takes place from the mucous membrane of the bladder, as well as from other mucous membranes, as that of the nose, throat, lungs, stomach, &c.; but it must not be forgotten that slight hæmorrhage is often the very first symptom of that terrible malady cancer of the bladder, and the practitioner should, therefore, in a doubtful case, always give a very guarded opinion.

I have seen small quantities of blood passed day after day by a healthy man just as micturition ceased. It seemed as if the effort to expel the last drops of urine had caused the rupture of a few capillaries about the membranous part of the urethra or neck of the bladder. The hæmorrhage ceased after a time without resorting to any special treatment.

The possibility of hæmaturia depending upon the presence of entozoa in any part of the renal apparatus must also be borne in mind.

419. Of the Treatment of Hæmaturia.—If the blood present in the urine has escaped from the kidney in consequence of acute congestion or inflammation, as may generally be determined by the

sudden accession of the symptoms—the small quantity of the urine, the presence of casts, with a considerable quantity of albumen, the occurrence of some amount of puffiness about the face, and perhaps lumbar pain—the case must be treated by rest, purgation, sweating, and, in bad cases, the patient should be cupped over the loins (*see* § 257).

If the escape of the blood from the kidney is due to a low state of health, or to a condition of system allied to that which gives rise to purpura, the treatment must be directed to improving the general health and the action of the stomach; tonics, the tincture of sesqui-chloride of iron or gallic acid, may be given; quinine, dilute acids, and pepsin, also do good. If hæmaturia occurs in the course of a case of scurvy, the scurvy, not the hæmaturia, must, so to say, be treated; lemon or lime juice, as generally given in this disease, will be of essential service.

In cases where the hæmorrhage depends upon calculus, rest in the recumbent posture, warm fomentations, small doses of opium by the mouth, and a suppository in the rectum will often afford relief (*see* also § 464 on the treatment of renal calculi).

Hæmorrhage from the kidney is not uncommon in cases of continued fever. Sometimes it occurs in the course of pneumonia; and I have seen it in three or four cases of acute rheumatism. In all these conditions the vessels of the kidneys and internal organs generally are highly congested. The symptom generally passes off after a few days, but in one case of acute rheumatism it persisted for three weeks, producing an anæmic condition; cupping over the loins and several remedies were tried, but did not seem to produce any immediate effect upon the hæmorrhage, which gradually subsided. Turpentine in this as well as in many other forms of hæmorrhage seems to do good in some cases. Acetate of lead in doses of three or four grains every three hours, for five or six doses, sometimes checks hæmorrhage. This remedy was much employed by Dr. Golding Bird. It is of course very important not to continue giving lead for any length of time, and it should be borne in mind that some persons are more susceptible to its influence than others. If the blue line should appear near the free edge of the gums, the lead must be stopped and its elimination promoted by purgatives and sudorifics.

Gallic acid is one of the most powerful remedies in hæmorrhage from the kidneys or bladder. It may be given in much larger doses

than usually recommended. I have given from ten grains to half a drachm five or six times in the twenty-four hours in many cases.

Hæmorrhage depending upon cancer of the kidney or bladder is sometimes one of the most formidable symptoms of this disease, and the treatment is necessarily only palliative. Gallic acid, opium, and complete rest sometimes afford great temporary relief. If in such a case the hæmorrhage is dangerous from its excessive amount, ice should be applied to the pubis, and styptics may be injected into the bladder; 20 to 40 grains of alum may be dissolved in a pint of water (Prout) and injected. I have never had occasion to resort to this plan. If the blood coagulates in the bladder, some trouble may be experienced in its removal, but gradually the clot becomes softened, and passes away piecemeal. The injection of water facilitates its expulsion.

420. Circular Sporules closely resembling Blood-Corpuscles. —Occasionally the sporules of fungi are found in urine which very closely resemble blood-corpuscles in size, and also in their general appearance. ("*Archives of Medicine*," Vol. II., p. 49.) Upon very careful examination, however, with a high power, a little eminence, which is the first commencement of the formation of a new sporule from the parent, may frequently be observed projecting from them. Not unfrequently two sporules may be seen together, one having grown from the other. Some sporules, resembling blood-corpuscles, are represented in Plate XXI., Fig. 113. They vary in size more than blood-corpuscles. A short time since, I received a specimen of urine from a friend which contained numerous sporules; and the resemblance to blood-corpuscles was so great that, had I examined the specimen carelessly, I should certainly have considered them to be of this nature. By using a power of seven hundred diameters, their characters were distinctly made out. In these cases, albumen due to the existence of kidney-disease may be found in small quantity, which would complicate the case, and increase the chance of our being led to form a wrong conclusion. When doubt exists, the deposit should be set aside for a few days, exposed to the air in a warm place, when the spores will germinate, and all question as to their nature will be removed.

Bodies rarely met with in Urinary Deposits, and Substances of a doubtful Nature.

Under this head I must include tubercle and cancer, and a few bodies of the nature of which I am not perfectly certain. Some of these substances have been carefully examined by other observers, but the results have not been sufficiently satisfactory to justify positive statements as to their nature.

421 **Cancer-Cells.**—In cases of cancer of the bladder, it is not uncommon to meet with well-defined cancer-cells in the urine. Some time since, Mr. Fergusson requested me to examine for him a small portion of gelatinous-looking matter, which had been passed by a patient suffering from bladder-affection. Of the exact nature of this matter there had been some difference of opinion. Upon treating a fragment of it with a little glycerine and water, and subjecting it to examination with a power of two hundred diameters, I had no difficulty in making out loops of capillary vessels covered with a thick layer of cancer-cells. The specimen presented the usual appearances which distinguish a cancerous tumour which is rapidly growing into a hollow viscus, and was evidently one of the tongue-like or villous processes, broken off from the mass. There could, therefore, be no further doubt as to the exact nature of the case. The diagnosis was confirmed by subsequent examination of the parts after the patient's death.

I have lately seen four cases of cancer of the bladder, in every one of which the disease was detected for the first time by the microscopical examination of the urine. In two of these cases, there was an abundant deposit of a dark brown colour, much resembling blood in appearance when it occurs in acid urine. This brown deposit was found to consist principally of a vast number of cancer "cells," varying greatly in form and size, most of them being very large. Many were of considerable length and contained "cells" in two or three different places. These so-called "cells" consist, in fact, of a soft material corresponding to the wall of a normal epithelial cell, in which masses of germinal matter are embedded in considerable number. A very good specimen of cancer-cells from the bladder is represented in Plate XXII., Fig. 119; and in Fig. 120, a young cell of normal bladder epithelium is seen. It is undergoing division; the cancer-cells multiply in the same way, but faster and

irregularly, instead of succeeding each other in an orderly manner, layer after layer.

From time to time, specimens of urine are sent for examination containing numerous well-defined spindled-shaped cells, which, from their general resemblance to the cells of scirrhus, are sometimes considered to prove the existence of this terrible malady in connexion with the kidney or bladder. In several such instances, I have no doubt that the cells in question have been derived from the ureter, and their presence was quite unconnected with disease. (Plates IX., XV., XIX., Figs., 46, 76, 100 *b.*) It is very important to bear in mind that the epithelium of the ureter, and some cells derived from certain parts of the mucous membrane of the bladder, very closely resemble in form and general appearance the drawings which are given of the cells of hard cancer.

422. Tubercle Corpuscles.—Tubercle is occasionally met with in urinary deposits. Dr. Thudichum ("*The Pathology of the Urine,*" p. 265) alludes to a remarkable and undoubted case which he saw in the Brompton Hospital. It is often very difficult to identify tubercular matter in sputum; and in many cases where the deposit escaped in the urine, the disintegration of the tubercular matter would be so great as to interfere with its detection. The characters of tubercle are represented in "*The Microscope in its Application to Practical Medicine,*" 2nd edition, pages 276 and 290.

423. Of the Clinical Importance of Cancer and Tubercle in the Urine, and of the Treatment of these Cases.—Unfortunately the very positive evidence of cancer-cells, afforded by microscopical examination, prevents us from giving any hope of a favourable termination of the case. The disease must sooner or later be fatal. In my experience the suffering is far less in those cases in which a large quantity of the cellular growth forms upon the surface of the mucous membrane, small masses becoming detached from time to time, than when the muscular coat of the bladder is the chief seat of disease. I have known cases of the former disease in which there was scarcely any suffering, the patients dying in from two to three years, after the cells were first found in the urine, from the gradual exhaustion caused by the hæmorrhage which sometimes takes place daily and never entirely ceases. The object of treatment is simply palliative. Tincture of the sesquichloride of iron or gallic acid will

restrain the hæmorrhage if very violent. It is important to keep the urine in as healthy a condition as possible. If it be either very acid or alkaline the patient's suffering will be increased. If the pain or irritability of the bladder is excessive we must give opium by the mouth or by the rectum.

424. Spherical Bodies containing Nuclei and Granular Matter.—Round structures presenting these characters are not unfrequently met with in specimens of urine; but I have not been able to determine with accuracy the portion of the mucous tract from which they are derived, or their pathological importance.

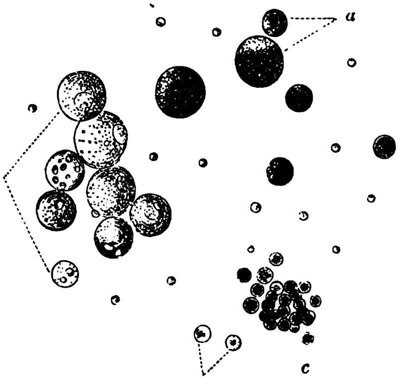
The cells represented in Plate XXII., Fig 114, were found in the urine of a patient suffering from rheumatic fever. *a.* In the natural state. *b.* Treated with acetic acid. *c.* Cells resembling pus. *d.* The same treated with acetic acid. The small circular bodies are altered blood-corpuscles. × 215.

The large cells above referred to contained several transparent bodies within them, which became very distinct upon the addition of acetic acid (nuclei?). The central bodies did not refract like, nor did they present the circular, dark, and well-defined outline, so characteristic of, oil-globules.

In Fig. 115 are represented specimens of large cells filled with dark granular matter, but not containing any oil-particles, from the urine of a case of chronic bronchitis. There were also a few pus-globules present in this specimen. Fig. 116 represents a curious cell found in the urine of a case of renal dropsy of seven weeks' duration. Casts of medium diameter, with a few small cells containing oil, were also present in the same specimen of urine. Of the nature of these bodies I am not certain, neither have I been able to ascertain from what part of the genito-urinary mucous membrane they have been derived. Every care was taken to prevent the presence of matters of extraneous origin; but it is not impossible that some of the peculiar cells have been derived from sputum which has been altered by the action of the urine.

Cells presenting somewhat similar characters have come under my notice in several other cases; and from that portion of the mucous surface of the bladder known as the trigone, I have obtained cells agreeing with them in general characters. It is not unreasonable, therefore, to assume that many of these peculiar cells are modifications of bladder-epithelium.

Fig. 114.



§ 424 × 215

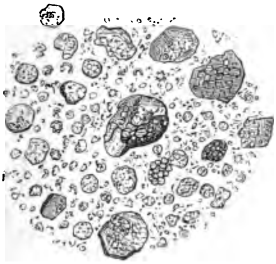
Fig. 115.

§ 424

Fig. 116.

§ 424

Fig. 117.



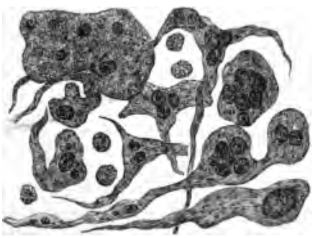
× 463

§ 418

Fig. 118.

§ 351

Fig. 119.



§ 421 × 215

Fig. 120.

§ § 353, 421 × 700

To face page 364.

425. Small Organic Globules.—Under this name, Dr. Golding Bird has described some little bodies smaller than the pus or mucus-corpuscles, with a perfectly smooth exterior, and unaffected by acetic acid. Dr. Bird suggests that they may be nuclei which have been set free from a cell by the bursting of the investing membrane.

Plate XXIII., Fig. 126, represents the appearance of the deposit from the urine of a patient suffering from calculus. The small round bodies represented in different parts of the figure were insoluble in strong acetic acid, and were unaltered on the addition of ether or potash. Many of them contained a central dark spot. They were accompanied with numerous small octohedral crystals of oxalate of lime. From their highly refractive properties and chemical characters just referred to, it is probable that they were composed of oxalate of lime.

Dr. Balfour, of Edinburgh ("*Edinburgh Medical Journal,*" Vol. I., 1856, p. 617, note), has shown that altered blood-corpuscles correspond to Dr. Golding Bird's 'small organic globules.' After the crenated margins, so often seen in blood-corpuscles in urine, have made their appearance, the globule undergoes further change, until at last it reassumes its spherical appearance, but becomes much smaller than before, and is not altered by hot or cold acetic acid. These so-called small organic globules may therefore consist of *little spherules of oxalate of lime*, *altered blood-corpuscles*, or the *sporules of fungi*. I have demonstrated the last in a great number of cases; and sometimes they form a "visible white deposit," such as Dr. Bird described. It is a pity that the name "organic globule" has been used at all, for certainly several widely different substances answer to the descriptions given of it. The so-called "large organic globules," or "exudation or granular corpuscles," have been shown to consist of an aggregation of fat globules. I have, therefore, thought it better, in order to avoid confusion, not to employ the term in this work. (*See* note on p. 284; also, "*The Microscope in Medicine,*" Second Edition, p. 326.)

Should the practioner meet with objects of the nature of which he is in doubt, he should at once make careful drawings, and take notes of the case in which they occurred. The importance of all microscopical observers being familiar with the appearance of all extraneous matters likely to be found in urine, has been dwelt upon in § 78, *et seq.*

CHAPTER XVII.

URINE IN DISEASE. OF ENTOZOA. *Hydatids—Echinococci—The Diplosoma Crenata of Dr. Arthur Farre—Dactylius Aculeatus—Strongylus Gigas—Distoma Hæmatobium—Other Worms passed from the Urinary Organs—Parasites and other Animals of accidental presence in the Urine—Elongated Clots of Fibrin and of Blood.*

ENTOZOA.

426. **Hydatids.**—*Echinococci* have been passed from hydatid cysts occupying the kidney, and have been found in the urine. The hooklets of these creatures are very characteristic, and would be found in the urinary deposit. Mr. Simon refers to a case in which small cysts were passed entire. In these rare cases, the symptoms of a tumour connected with the kidney are present. At length the cyst bursts; the fluid with echinococci is discharged in the urine; and perhaps some fragments of the cyst also escape. These and the hooklets of the echinococci are perfectly characteristic, and cannot be mistaken for anything else. An account of a recent case is given by Mr. Curling in the "*Medical Times*" of August 15th, 1863. Mr. Curling gave me several of the hydatids passed by this patient. I could not find any echinococci or hooklets, but there could not be the smallest doubt as to the nature of the cyst. Echinococci are represented in Plate XXIII., Fig. 121, and the hooklets in Fig. 123. (Dr. Sieveking, "*Lancet,*" 1853; Mr. Simon, "*Lancet,*" 1853; "*Glas-*

gow Medical Journal," 1856; "*Med. Times and Gazette,*" 1855. For the Characters of Echinococci, see "*The Microscope in Practical Medicine,*" Second Edition, p. 361.)

427. Diplosoma Crenata.—The most remarkable case on record in which worms were passed from the urinary bladder, is one which is reported by Dr. Arthur Farre, who has made some most careful dissections of the worm, and observations on the anatomy of the ova. ("*Archives of Medicine,*" Vol. I., p. 290.) This is the case recorded by Mr. Lawrence in Vol. II. of the "*Med. Chir. Trans.*" in the year 1811. It is the only one on record. Dr. Farre describes the general characters of the worm in the article "Worms," *Library of Medicine,* Vol. V., p. 241. Rudolphi, on insufficient evidence, declared that these worms were merely lymphatic concretions; and in consequence this interesting and authentic case has not yet been properly noticed by writers on parasites. From the recent re-investigation of the whole subject, there can be no doubt that Rudolphi was wrong in his conclusions, and that these were real sterelminthous worms. In his paper above referred to, Dr. Farre at once sets all doubt on the question at rest. He now describes the minute anatomy of the worm and the characters of the ova.

The patient was a woman twenty-four years of age; and, during the course of two or three months, she passed as many as from eight hundred to a thousand worms. The worms were of two different kinds. The first form, which varied from four to six inches in length, were passed in great number. The other kind was smaller, varying from half an inch to an inch in length. These worms were passed on one occasion only; they lived in the urine for three days, and moved very briskly. They belong to the genus spiroptera, and Rudolphi gives to them the name of spiroptera hominis. The larger worms have been named by Dr. Farre, from their body being double, diplosoma crenata. Fig. 122, Plate XXIII., represents the general characters of the worm, one-half the natural size. The drawing represents one of the largest and most perfect specimens of the entozoon, half the natural size. In the centre, at the upper part of the figure, is the sharp twist or kink, where the body is most contracted. From this point each half gradually enlarges to a certain distance, but tapers again towards either extremity; the right half terminating, in this specimen, in a point, the left furnished with a

lateral membranous flap. This half of the body shows the abdominal groove, and double crenate border. The right half, being spirally twisted, exhibits successive portions of the dorsal, lateral, and abdominal surfaces. This twisting is observable in many specimens. Towards the extremity of this half, numerous fibrous cross-bands are shown. The minute structure of this creature is very peculiar, and has been accurately investigated by Dr. Farre, who has illustrated his remarks with numerous drawings. There can be no doubt that, in this unique case, two new forms of intestinal worms, never seen before or since, were passed from the bladder in considerable number. For the details of the case, and for the account of the structure of the worms, I must refer to Dr. Farre's original paper in my "*Archives.*"

428. **Dactylius Aculeatus.**—The only case on record in which this parasite has been found in connexion with the urinary organs, is that of a girl aged five years, who was under the care of Mr. Drake. Several worms were voided; and some of them were carefully examined by Mr. Curling, whose memoir, with drawings of the worm, is published in the twenty-second volume of the "*Transactions*" of the Medico-Chirurgical Society. The female was four-fifths, and the male only two-fifths of an inch in length. The tegument was armed with spines, occurring in clusters. The worms exhibited active movements; and, if left in the urine, they lived for two or three days. There were no symptoms in the case pointing to any derangement of the urinary organs. They were first noticed in the urine on May 26th, 1839, and on several occasions between this date and June 11th, after which no more worms were passed. These entozoa were, therefore, only found during a period of sixteen days, and they were not present each day.

429. **Strongylus Gigas.**—This parasite appears to have been found in the human kidney on one occasion, although Küchenmeister comes to the conclusion that it has never been met with. The specimen is preserved in the Museum of the College of Surgeons. It is occasionally found in the lower animals. A few years since, I found three beautiful specimens of the worm, two males and one female, coiled up in the kidney of a large dog. The female was about 15 inches in length, and rather less than half an inch in diameter. The skin was of a very bright blood-red colour, mottled

with black. The males were about nine inches long, of a reddish brown colour, and about a quarter of an inch in diameter. The kidney was reduced to a mere fibrous cyst, rather larger than the organ on the opposite side; and the three entozoa were coiled up together, and occupied its entire cavity. The ureter was pervious all throughout, and over its surface, and embedded in the mucus of the bladder, were multitudes of ova. Ova were passed in great number in the urine of this dog. The kidney and the female worm are preserved, and still in my possession.

430. Distoma Hæmatobium has been found in the bladder, ureters, and pelvis of the kidney, as well as in the veins of the intestine, in the portal veins, small intestine, gall-bladder, &c. Griesinger states that this parasite is very abundant in Egypt. The eggs of the worm were embedded in the mucous membrane of the bladder, which was much congested and ecchymosed in these situations. The worms themselves appear to have been found in the vessels. The eggs often form the nuclei of small deposits of uric acid. They have been found adhering to the mucous membrane of the bladder, kidneys, and ureter.

431. Other Worms passed from the Urinary Organs.—A case is related by Raisin in which a worm three inches long was passed by a man fifty years old. Moublet alludes to the case of a boy aged 10, who voided four worms from four to five inches long, accompanied by pus. Other instances are recorded, but these do not seem to be well authenticated.

432. Parasites and other Animals of accidental presence in Urine.—Intestinal worms are sometimes passed into the vessel containing the urine, and the patient not unfrequently affirms that they came from the bladder. Various species of acari are frequently met with in urine. It need hardly be said they were not formed in the urinary organs. Insects and their larvæ are from time to time found in urine. Patients will positively assert that larvæ of the common flesh-fly have been passed through the urethra. I have on many occasions had specimens of the common maggot and cheese maggot forwarded to me, with the positive assurance they had been voided by the patient. The presence of the tracheæ in every part

of the body prove the creature to be an insect, and it need scarcely be said that an air-breathing insect could not have been developed in any part of the urinary organs. These insect larvæ will pass through the entire tract of the intestinal canal in a living state. (*See* "*The Microscope in its Application to Practical Medicine*," and papers by Dr. Brinton and Mr. Blood in Vol. III. of my "*Archives*.")

433. **Elongated Clots of Fibrin or of Blood** are occasionally mistaken for intestinal worms. Microscopical examination will enable any one at once to distinguish them.

CHAPTER XVIII.

OF URINARY CALCULI.—*General Consideration of the Subject—Animal Matter in Calculi—Of the Concentric Layers—Of the Classes of Urinary Calculi, and of the Chemical Examination of Calculi—Tests kept in Small Bottles with Capillary Orifices.* CLASS I. *Calculi which leave only a Trace of fixed Residue after Exposure to a red Heat—Uric Acid Calculi; Chemical Characters—Calculi composed of Urates; Chemical Characters—Uric Oxide, Xanthic Oxide, Xanthine—Cystic Oxide or Cystine—Fibrinous Calculi—Fatty Concretions.* CLASS II. *Calculi which leave a considerable Quantity of Fixed Residue after Exposure to a red Heat—Oxalate of Lime Calculi; Chemical Characters—Calculi composed of Earthy Phosphate; Chemical Characters—Carbonate of Lime Calculi—Silicic Acid Calculi—Prostatic Calculi—Summary of Chemical Characters of Calculi—Of the Origin and Formation of Urinary Calculi, and of the Nature of the Nucleus—On the relative Frequency of the Occurrence of the different Calculi—On the importance of the administration of increased quantities of Fluids in certain Calculous and other affections—On the methods of dissolving Urinary Calculi—On dissolving Calculi by Electrolysis—Lithotomy and Lithotrity.*

434. General Considerations on the Formation of Calculi.—As there are several substances in healthy urine possessing but a slight degree of solubility, which, in certain derangements of the physiological actions of the body, are produced in much larger proportion than in health, while other matters not present in healthy urine, and not readily soluble in water, are sometimes

formed, it is not to be wondered at that from time to time some of these matters are slowly deposited in the insoluble form from the urine while it yet remains in the bladder, or even before it reaches this organ. It is very interesting to consider the nature of the various conditions which are likely to lead to this deposition of insoluble calculous matter, and it is instructive to study the condition of the system in relation to the particular form of insoluble matter that may be deposited. If we were accurately acquainted with the mode of deposition of calculous matter, it is very possible that we might lay down such rules for the guidance of patients in whom this tendency existed as would prevent the formation of the stone, or retard its increase if already formed. The deposition of a calculus does not always depend upon the state of the urine; for it is possible that the urine may be healthy while a stone is forming, and that the changes taking place on the surface of the stone itself may cause the precipitation of insoluble substances. Remedies which act on the kidney in many cases exert no influence upon the formation of a stone. It is very important in connexion with this subject to study the general chemistry of the body carefully; for it will often be found that the tendency to calculus disorder is explained by deranged chemical changes, which may perhaps be materially modified by attending to the action of the alimentary canal and skin, altering the mode of living, and administering the salts of the vegetable acids, alkalies, mineral acids, or mere diluents in large quantity, according to the nature of the case.

In those cases in which the deposition of the calculous matter mainly depends upon the urine being in a state unfavourable for holding certain slightly soluble matters in solution, it follows that the tendency to deposit may be averted, if the condition of the urine can be altered. It is possible that at one time an acid state of urine may favour the precipitation of uric acid; while, after a short interval, its characters may become so altered that it becomes alkaline. Not only does the precipitation of uric acid cease, but phosphates, which are insoluble in an alkali are deposited. Phosphatic salts are soon deposited on the uric acid, and it is by them effectually protected from the further solvent action of an alkali.

435. Animal Matter in Calculi.—Calculi often consist of many different constituents; but usually one predominates greatly over

the rest, and the calculus is named accordingly. Even the purest calculi composed of earthy salts contain, nevertheless, a certain quantity of organic matter; and those which seem to consist of organic material only, contain a certain proportion of earthy salts. A certain amount of animal matter is deposited with the hard material, and in many cases serves to agglutinate the particles together. The precipitation of any saline matter in a viscid substance like gum or mucous will be deposited in the form of a spherical mass instead of in its usual crystalline form. (*See* Mr. Rainey's "*Observations on the Formation of Shell, &c.*") After the hard matter of a stone has been dissolved, this animal matter may be seen in the form of a translucent, granular, mucus-like mass. Upon microscopical examination, sometimes the remains of delicate fungi can be detected in this matrix, and very frequently dumb-bells of oxalate of lime, or fragments of them, are found. The fungi were formed during the formation of the calculus; and it is probable that the reaction developed in the fluid in contact with them during their growth caused the continued precipitation of the insoluble matter.

The hard calculous matter may consist of substances which exist in healthy urine, like *phosphates* and *uric acid*, slowly deposited from their weak solution in the secretion; or of materials which are not present in perfectly normal urine, such as *oxalate of lime*, *cystine*, &c.

436. Of the Concentric Layers of Calculi.—The insoluble material is deposited in distinct layers, which can often be readily detached and separately examined. These layers are easily demonstrated by making a section of the calculus, which can, except in the case of the hardest and most brittle calculi, be readily effected as follows. The calculus is to be sawn through with a fine sharp saw. The cut surface is next to be ground smooth, by being rubbed down upon a smooth flat hone with water. When it is perfectly even, it may be washed and allowed to dry. Lastly, the cut surface is to be varnished; and now all the different layers will be seen most distinctly. If the calculus be very brittle and hard, unless it be sawn through with a diamond wheel, it is better to grind away one-half without attempting to saw through it. Small calculi are very easily ground and polished, and often furnish very instructive specimens.

The concentric layers are often of different colours, of different degrees of hardness, contain various proportions of organic base, and are of different chemical composition. Each ring forms the section of a layer, and a portion of each may be detached and chemically examined separately. Some of these layers are deposited quickly, others more slowly; and they therefore vary considerably in hardness. In examining a calculus, it will be necessary to subject a small portion of several layers separately to examination.

Concentric layers may be demonstrated in the most minute calculi, even in those microscopic calculi which require to be examined under a power of 250 diameters. (*See "Illustrations," Calculi*, Plate I., Figs. 1, 2, 3, 4.)

Seldom can any definite crystalline form be made out, except upon the surface of the concretion; and upon examining small portions of a calculus in the microscope, nothing but a great number of crystalline fragments, exhibiting concentric layers, can usually be distinguished. Sometimes the material is at first deposited in separate little spherical masses, which become aggregated and at length become incorporated together. Although distinct names are assigned to different forms of calculi, a concretion entirely composed of only one substance is seldom met with.

Of the Classes of Urinary Calculi, and of the Chemical Examination of Calculi.

For convenience of description, calculi may be arranged in two classes, according to the relative proportion of the organic matter and inorganic salts present. The *combustible*, or *almost entirely combustible* calculi, are those which leave very little residue after exposure to the action of a red heat on platinum foil; while the *partially combustible* or *incombustible* calculi leave a considerable proportion of fixed residue.

437. I. The first class will include calculi composed of *uric acid, urates of ammonia, soda, lime, and magnesia*, and the rare forms of *uric* or *xanthic oxide calculi*, *fibrinous* and *blood calculi*, and those consisting of *cystine*.

438. II. The second class will contain the *oxalate of lime or mulberry calculus;* the calculi composed of various *phosphatic*

deposits; that consisting of *carbonate of lime*, very rare in the human subject, but not uncommon among the lower animals; and the *silicic acid* calculus.

The first preliminary test to which a portion of calculous matter of unknown composition is subjected, consists in exposing it to the action of a red heat. When reduced to a fine powder, a little is placed upon a piece of platinum foil, and heated in the flame of a spirit-lamp. If a carbonaceous mass remain, it is to be exposed for some time to a red heat, until it is entirely dissipated, or until nothing but a white ash remains.

If it be almost entirely dissipated, the original powder is to be tested for *uric acid, urates of soda, lime, ammonia, or cystine*, according to the method described for testing for these substances occurring in the form of urinary deposits.

If the powder be incombustible, or only *partially combustible*, it is to be tested for *phosphate of lime, triple phosphate*, and *oxalate of lime*, by the methods indicated. (*See* Table VI.)

439. Tests kept in Small Bottles with Capillary Orifices.— In Chapter I. I have directed attention to a very convenient plan of keeping reagents, which is not only applicable to the subject now under consideration, but will be found of great advantage in all cases in which only a very small portion of matter is to be subjected to examination, particularly in ascertaining the chemical characters of substances which form the subject of microscopical inquiry. The plan of examining the chemical composition of a substance which I am about to describe may be termed not inaptly *microscopical testing*. A chemist may carry his laboratory in his pocket; and the physician may take all the apparatus necessary for the most complete qualitative examination he is ever called upon to make, in a space much less than that now usually occupied by the urinometer, spirit-lamp, and acid-bottles.

These little test-bottles have been arranged in a case, with the urinometer and other apparatus required for the examination of urine. The mode of filling these test-bottles is described in § 34, p. 8. When we proceed to test a small portion of calculous matter, it is to be powdered, and placed on a glass slide. The cap is removed from the test-bottle containing the appropriate reagent, which is then inverted, and its capillary extremity placed near to

the matter or drop of solution to be tested. The warmth of the hand expands the air contained in the bottle, and a drop of the liquid is expelled. In this way, a drop of an unknown solution can be readily subjected to the action of several tests, and indications of the presence of certain substances may be obtained as clearly as if much larger quantities were operated on.

440. Testing for Carbonates.—In testing for carbonates, the powder or solution may be lightly covered with a piece of thin glass, and the acid subsequently added; the slighest effervescence becomes at once clearly perceptible; and, if necessary, the specimen may be subjected to microscopical examination, and thus the smallest disengagement of air-bubbles can be detected.

Class I.—*Calculi which leave only a trace of fixed residue after exposure to a red heat.*

441. Uric Acid Calculi.—Nearly two-thirds of the calculi in the museums of this country consist in great part of uric acid. They vary very much in size. Small uric acid calculi are sometimes formed in great number in the kidney. For the most part, the deposition of the uric acid commences in the kidney itself; and not unfrequently the small concretion becomes impacted in the lower part of the uriniferous tubes or infundibula, and gives rise to great irritation, until it becomes released, and passes down the ureter into the bladder. It may now pass off by the urethra; or may remain in the bladder, when layer after layer is added, until it attains a considerable size.

The uric acid calculus is usually of an oval form, but somewhat flattened on two of its surfaces. A large uric acid calculus consisting of concentric layers of uric acid, deposited upon a smaller calculus composed of oxalate of lime, is represented in Plate XXIV., Fig. 127. It is sometimes quite smooth externally, sometimes rough, or covered with a number of rounded projections. It is generally of a brownish hue, varying from a pale fawn colour to a dark brownish red. Dr. Rees met with one specimen in which the nucleus was quite white, and was composed of pure uric acid destitute of colouring matter. The consistence of the uric acid calculus is usually hard, and its texture compact, but rarely it is soft, and can be broken down

between the finger and thumb. It breaks up into small angular pieces.

I have examined many small uric acid calculi, and in several instances have found that the nucleus consisted of matter insoluble in potash, which polarised readily; and, in some specimens, well defined dumb-bell crystals of oxalate of lime were discovered. In some few cases, the nucleus probably consisted originally of mucus or some soft matter, which after a time had shrunk and nearly dried up, leaving a space or cavity in the centre of the calculus; but, even in these, matter insoluble in potash and acetic acid exists. Very generally, dumb-bells of oxalate of lime form the nucleus of uric acid calculi.

The uric acid calculus is often coated with phosphates. The irritation of the calculus, according to Dr. G. O. Rees, excites the secretion of an abnormal quantity of alkaline fluid from the mucous membrane of the bladder, which causes the earthy phosphates to be precipitated from their solution in the urine. If ammonia were set free by the decomposition of the urine, it is possible that a little of the uric acid calculus might even be dissolved; but this would soon be prevented by the deposition of earthy phosphate upon the surface. The phosphates are not *secreted* in increased quantity by the mucous membrane of the bladder, as was formerly believed, but are merely precipitated from their solution in the urine.

442. Chemical Characters.—Insoluble in boiling water, soluble in potash. From the alkaline solution, crystals of uric acid may be obtained by adding excess of acid. The murexide test may be applied. (*See* Uric Acid, § 398.) When heated on platinum foil, it evolves an odour of burnt horn. Carbonate of ammonia and hydrocyanic acid are among the products of decomposition. The small amount of residue which remains after the ash has been exposed to a red heat for some time, consists principally of phosphates and carbonates of soda and lime.

443. Calculi composed of Urates.—These calculi usually contain urates of soda, ammonia, and lime; and very commonly small quantities of oxalate of lime are deposited with the urates. This calculus is in great part soluble in boiling water, and gives off ammonia when heated with a strong solution of bicarbonate of potash. Dr. Prout states that it is principally met with in children, and is

usually small in size, of a pale brown colour. Layers of urate are often found in uric acid calculi.

444. Chemical Examination.—After treating the calculus with boiling water, the insoluble matter is to be separated by filtration. This may consist of oxalate of lime and phosphates. If only a little boiling water has been added, the urate will be deposited as the solution cools. The solution is to be tested as follows. Acetic acid will precipitate the uric acid. The mixture is to be filtered, and the filtered solution evaporated to dryness. The residue is to be exposed to a red heat. Carbonate of soda and carbonate of lime remain. The last may be obtained by solution in acetic acid and precipitation as oxalate.

445. Uric Oxide, Xanthic Oxide, Xanthine.—These names have been given to a rare form of calculus, which has only been found in man on three occasions. It is not soluble in water; it is hard, of a yellowish brown colour, and the surface can be polished by friction. Scherer has found xanthine in the liver and spleen, in muscle, and in blood. It is closely allied to uric acid, and also to hypoxanthine, which only differs from it in containing two atoms more of oxygen. (*See* § 401.)

446. Cystic Oxide, Cystine.—This form of calculus is of a pale greenish colour; its surface is smooth, and there are no indications of concentric layers. The fracture is glistening, and the structure is semitransparent.

The chemical characters of this calculus are the same as those of cystine. (*See* § 411.)

447. Fibrinous Calculus.—This form was first noticed by Dr. Marcet, and it appears to consist entirely of an elastic organic substance closely allied to fibrine. It is said to resemble yellow wax in its appearance. It dissolved in potash, but was precipitated by excess of acid. It was insoluble in water, alcohol, and ether; but was dissolved by acetic acid, with the aid of heat. In this solution, ferrocyanide of potassium produced a precipitate. It left very little fixed residue after exposure to a red heat.

448. Blood-Calculi.—Dr. Scott Alison furnishes the following interesting remarks with reference to a case in which he discovered

some blood-calculi in the kidney. ("*Archives of Medicine*," Vol. I., p. 245.) Upon examining the body of a man named William Solly, who was admitted into the Consumption Hospital, Brompton, under the care of Dr. Cursham, on August 23rd, and who died on the 30th of the same month, the left kidney was found by Dr. Alison to be greatly wasted and changed in structure. The infundibula and pelvis were stuffed with hard bodies, most of which were of a coal-black colour. "The black calculi occupied the pelvis, while the infundibula were tenanted with a few calculi of a whitish-grey colour, with one exception small in size, about the magnitude of pear-seeds, and wanting the ordinary physical characters of phosphate of lime. One calculus, which occupied an infundibulum, is the size of a horse-bean, looks somewhat worn and disintegrated, and at one point resembles a piece of decayed wood. At one side it is black, from the presence of altered blood. It is very light in weight, and is composed of blood and phosphate of lime. The black calculi, which form the chief point of interest in the case, were about six in number, and ranged from the size of a coriander-seed to that of a small horse-bean. When found, these black calculi were tolerably hard; but, being friable, they partly broke asunder in handling. The fractured surface varied a little in colour, in some parts presenting a dark rusty tint." Liquor ammoniæ dissolved them; they were capable of partial combustion. The microscope revealed only amorphous particles; but Dr. Owen Rees, with the assistance of a neutral saline solution, discovered forms which he considered to be the remains of blood-corpuscles.

The kidney was remarkably altered. It was very small, but retained somewhat of the normal shape. It weighed only an ounce and a half, and was only two inches in length. Its colour was drab; its consistence was firm and fibrous. At one extremity only could any natural cortical or tubular structure be found. The organ resembled a sac with thin irregular walls. The lining membrane appeared healthy. The renal artery was small, thickened, and scarcely admitted a common probe. The ureter was small, but less out of proportion than the artery. The investing membrane could not be separated from the other parts with which it was connected.

"The atrophy of the kidney in this case was probably brought about by the production of inflammatory action, set up, perhaps, by the presence of small calculi of phosphate of lime. Blood was pro-

probably effused in consequence, and, from suppression of urine, remained in the infundibula and pelvis, and failed to be washed down the ureter. This blood hardening would form the calculi which were discovered. After the abatement of the supposed inflammatory action, degenerative processes would supervene, and lead to the remarkable atrophy and change which the kidney presented. The duties of this altered kidney would be thrown upon the other; but, as the system was much wasted by disease, no increase of size would result.

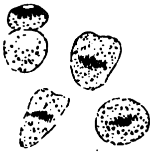
"Only a very imperfect history of the patient could be obtained, he being very exhausted when he came into hospital. Since his death, inquiries have been made for information, but with little success. He was fifty-two years old, and by trade a painter. He had been ill with cough two years, and his feet and legs became œdematous only two weeks previous to his decease. No information could be obtained respecting his having suffered from calculi in the bladder, or from hæmaturia; but it is right to mention that no member of the family of the deceased could be found."

449. Fatty Concretions.—These have been already alluded to under *Urostealith* (§ 340). Specimens of urine which contain large lumps of hard fatty matter will sometimes be brought for examination. Quite lately I have seen two such specimens, which were said to be cases in which concrete fatty matter had been passed in the urine. In these, however, the fat was ordinary suet, as was proved by the presence of the fat-vesicle, white and yellow fibrous tissue, and fragments of vessels.

Class II.—*Calculi which leave a considerable quantity of fixed residue after exposure to a red heat.*

450. Oxalate of Lime Calculi.—I have seen an oxalate of lime calculus not larger than the 1-500th of an inch, and have traced the formation of these stones through their several stages. I believe that the dumb-bell crystals formed in the kidney, in the first place become aggregated together, forming small collections, as represented in Plate XXIII., Fig. 125; crystalline matter is then deposited in the interstices, and gradually a microscopic calculus results. A beautiful specimen of a microscopic oxalate of lime calculus is represented

Fig. 121.



× 42

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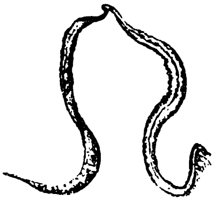
Fig. 122.



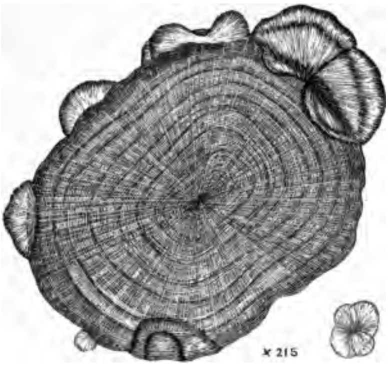
§ 427

Fig. 123.

× 125

§ 426

Fig. 124.



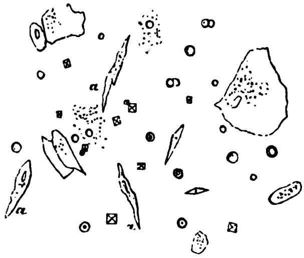
§ § 405, 459

Fig. 125.

× 215

§ 405

Fig. 126.



× 215

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in Fig. 124. At *a*, a much smaller microscopic calculus is seen, consisting of only two dumb-bells.

These minute calculi remain probably for some time in the kidney, and slowly increase until they form the concretions known as the hempseed calculi. Not unfrequently a number of them are found in the kidney, and pass down the ureter one after the other at various intervals of time. Sometimes one becomes impacted, and gives rise to the most serious and distressing symptoms. Having arrived at the bladder, the slow deposition of the oxalate may continue, or layers of uric acid or phosphate may be deposited, according to the state of the urine.

In cases where the oxalate increases, the surface becomes tuberculated, in consequence of the irregular deposition of the salt; the colour varies from a pale brown to a dark brown purple. They are commonly called the mulberry calculi. Such stones often attain a large size. They are very heavy and hard. On section, the laminæ are well seen, and it is often noticed that the calculous matter has been deposited most unequally.

Occasionally the oxalate of lime is deposited almost colourless and crystalline. Dr. Prout figures one of these calculi. I have a beautiful specimen, which was given me by Dr. Gibb, and was obtained from the horse. Large octohedral crystals of oxalate of lime can be seen all over the surface. The small hempseed calculi, which are white on the surface, also exhibit numerous beautiful crystals, although they are smaller than those referred to in the last specimen.

A beautiful example of another form of oxalate of lime calculus, the surface of which is of a pale brown colour, and the tubercles small and delicate compared with the mulberry calculus, is represented in Fig. 131, Plate XXIV.

Occasionally, however, in *post-mortem* examinations, we are somewhat surprised to find these calculi in the kidney, although the patient never suffered from the slightest symptom during life. I have a calculus the size of an almond, which I found fixed very firmly in one of the ureters of a man who died of another malady. Although its surface is rough, and it is half-an-inch in diameter, it caused scarcely any uneasiness, and there was no suspicion of its existence before the patient died.

The large mulberry calculus represented in Fig. 128 was removed

from a man aged 45, by Mr. James H. Ceely, of Aylesbury. The drawing is from a photograph, and represents the calculus two-thirds of its real size. Mr. McCormick sent me the following history of the case. It is not a little remarkable that a rough calculus like this, weighing twelve drachms, should have been present without causing great pain and uneasiness:—

"At the age of 15 years the patient (now 45) suffered from pain in the hypogastric region, extending along the urethra to the glans penis. At intervals during the succeeding twelve months the pain was very violent, and was at each attack followed by the evacuation of bloody urine. Occasionally since then he experienced pain in these situations, while taking horse exercise, or during unusual exertion, but *never to any great extent, and he was never compelled to seek advice.*

"With these exceptions his general health, although delicate, had been good till last June (1858), when he had an accession of symptoms resembling those mentioned, but greatly aggravated. The urine, in addition to blood, contained 'gravel.' At this time he consulted Mr. Reynolds, of Thame, who detected a vesical calculus, and on the 20th September, Mr. J. H. Ceely, performed the lateral operation and removed a rough, irregular, mulberry calculus, weighing twelve drachms.

"During the first ten days subsequent to the operation, the urine contained considerable quantities of pus and blood, after which time all abnormal characters disappeared, and the patient was discharged from the Bucks Infirmary perfectly well on the 8th of October, and had suffered little pain or inconvenience. This patient had enjoyed excellent general health during a period of twenty-nine years, notwithstanding the presence of a calculus probably during the whole period."

Another mulberry calculus, which was of a beautiful plum colour, is represented in Plate XXIV., Fig. 29.

A calculus of very curious shape, the nucleus of which consisted of oxalate of lime, is described by Mr. Price in the eleventh volume of the "*Transactions*" of the Pathological Society. Mr. Price removed fourteen calculi from the bladder of an old man by the lateral operation of lithotomy. Two of the calculi were peculiar in possessing several spine-like projections. The largest of these was about the size of a chestnut, and from its surface projected from eight

to ten spines, two of which were upwards of half-an-inch in length. Surrounding the oxalate of lime nucleus were several layers of uric acid and urates, with some earthy phosphate. The spines were formed of the latter salts alone, and there was no projection of the oxalate of lime nucleus into them.

The cause of their peculiar shape could not be ascertained. The stone was not in any pouch in the bladder, but was free in its cavity, and the absence of any spines projecting from the nucleus militates against the idea of the peculiar form having been given to it while in the kidney. No *post-mortem* was allowed. It seems possible that the formation of the spines might have depended upon the more rapid deposition of calculous matter on those parts opposite to the intervals between the smaller calculi, than over the part of the surface in immediate contact with them. Only the two largest calculi exhibited this peculiarity.

451. Chemical Characters.—The powdered calculus is soluble in the mineral acids, and the oxalate of lime is precipitated as a white powder by ammonia. Acetic acid will not dissolve oxalate of lime. After the powder has been exposed on platinum foil to a dull red heat for some time, a white ash consisting of carbonate of lime remains. This gives off bubbles of carbonic acid when it is treated with an acid. If the temperature be much higher than a dull red heat, a certain quantity of the carbonate of lime undergoes conversion into quick lime, which does not effervesce on the addition of an acid.

452. Calculi in Patients who have had Cholera.—The circumstances under which oxalate of lime is deposited in the form of the dumb-bell crystals have been already alluded to. It is interesting to find that both Dr. Prout and Kletzinsky have noticed deposits of oxalate of lime in patients who had had cholera, in which disease the fluids are in a high state of concentration. In *two* cases of this disease dumb-bells of oxalate of lime were found in the urine by myself. Dr. Prout also alludes to the frequency of cases of *calculous disease* in those who had suffered from cholera. These are important facts in favour of the view I entertain with reference to the formation of the nucleus of the calculus, which I have, in fact, shown to be in many cases a microscopic calculus. The concentration of the the fluids which occurs in cholera and other cases is

favourable to the deposition of the least soluble substances in a solid form. The intermediate stages between dumb-bells and small calculi have been actually observed, as I already mentioned.

453. Passage of Oxalate of Lime Calculi from the Kidney.—Oxalate of lime calculi often give rise to extreme pain when impacted in the kidney, and while passing down the ureter, or lodged in the bladder. In the kidney the pain is often of the most violent character, and frequently the patient suffers from many attacks before the stone is dislodged. Very frequently hæmorrhage occurs, and sometimes inflammation is excited, which terminates in the suppuration of the tissues contiguous to the stone.

On the other hand in many instances they pass without giving rise to the least inconvenience; indeed, I have known cases where a calculus has passed down the ureter without the patient even being conscious of it.

454. Calculi composed of Earthy Phosphate.—Both phosphate of lime and ammoniaco-magnesian phosphate enter into the composition of calculi. Dr. Prout showed that the phosphates were very often deposited upon other calculi, while there were very few instances in which uric acid, urates, or oxalate of lime, were deposited upon the phosphate. These two earthy salts enter into the composition of the *fusible calculus;* its degree of fusibility varying according to the proportion of triple phosphate present. The latter substance is easily fused in the blowpipe flame, while the phosphate of lime is quite infusible.

When the calculus contains but a mere trace of triple phosphate its structure is dense and even, it is heavy, and its surface is smooth and polished; but large calculi of this kind are exceedingly rare. A small quantity of triple phosphate is almost always present in the large calculi. Portions of the laminæ of these calculi are easily broken off.

Phosphatic calculi are represented in Figs. 130, 132, Plate XXIV. In both specimens the composition of the nucleus is different to that of the body of the calculus. In Fig. 132 a small uric acid calculus, with some oxalate of lime, is seen in the centre of the phosphatic mass.

Phosphate of lime calculi are often found in the kidney. In some cases the whole of the pelvis is occupied with calculi, varying

Fig. 127.

§ 441

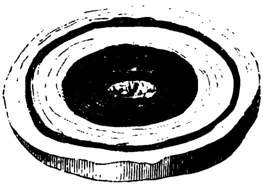
Fig. 128.

§ 450

Fig. 129.

§ 450

Fig. 130.



§ 454

Fig. 131.

§ 450

Fig. 132.

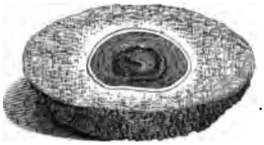


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Fig. 133.

§ 458

To face page 384.

in size and shape, mixed with a considerable quantity of pulverulent matter like fine sand. Each particle of this is found, upon microscopical examination, to consist of a minute calculus, containing a certain quantity of organic matter, probably mucus and disintegrated epithelium, for its nucleus. Several of these calculi are represented in the "*Illustrations*," Calculi I., Fig. 1.

Occasionally a phosphatic calculus, lodged in the pelvis of the kidney, gradually increases until a large calculous mass is formed by the deposition of earthy salts, layer after layer, until the whole pelvis of the kidney is occupied with it, and its prolongations extend into the infundibula and calyces.

The calculus, which consists almost entirely of triple phosphate, has a very porous structure; it is light, easily broken down by pressure, and perfectly white. Its surface is rough, and large crystals of triple phosphate can often be discerned upon the surface with an ordinary lens.

In the deposition of phosphatic calculi, the alkali which causes the precipitation of the phosphates is secreted, according to Dr. G. O. Rees, by the mucous membrane of the bladder. The earthy salts are precipitated from the urine, not *secreted* from the mucous membrane, as was formerly supposed.

Mr. Charles Hawkins sent me several small calculi which had been passed by a patient, to the very large number of 600, in a fortnight or three weeks. They were all about the size of a small pea. The surface exhibited several flattened sides, evidently caused by so many being formed together. They looked very like small biliary calculi which had been packed together in the gall bladder. The matter of which they were composed consisted of phosphate of lime and ammoniaco-magnesian phosphate, with a considerable quantity of organic matter. Although these calculi were, in many respects, like prostatic calculi, it is almost certain that they came from the pelvis of one kidney.

455. Chemical Characters.—The phosphate of lime calculus is infusible. It contains, like other calculi, a little animal matter, but this is often so small that laminæ, which have been exposed to a red heat, retain their general characters after ignition. It is soluble in the mineral acids, and slowly in acetic acid. Phosphate of lime is precipitated in an amorphous form when the acid solution is neu-

tralised with ammonia. When oxalate of ammonia is added to the acetic acid solution, a precipitate of oxalate of lime is formed.

The calculus composed of triple phosphate and phosphate of lime is fusible. The solution in acids, when neutralised by ammonia, gives a precipitate of ammoniaco-magnesian phosphate in stellate crystals, and a little phosphate of lime in an amorphous form. The quantity of phosphate of lime present is sometimes so small, that the solution in acetic acid does not give a precipitate when oxalate of ammonia is added. Calculi, composed of triple phosphate, generally contain more mucus and organic matter than the other phosphatic calculi.

456. Carbonate of Lime Calculi, though common among herbivorous animals, have rarely been met with in man. They are friable, and sometimes perfectly white. Mr. Smith has described some which are very like the mulberry calculi ("*Med.-Chir. Trans.*," Vol. IX., p. 14). There are specimens of this form in the Oxford Museum, among Mr. Hitching's collection, but, unfortunately, no history is attached to them. Dr. Thudichum states that he has examined prostatic concretions which consisted almost entirely of carbonate of lime. A small quantity of carbonate of lime is usually deposited with the earthy phosphates.

This calculus effervesces freely when exposed to the action of acids previous to incineration; white oxalate of lime yields carbonate only after having been exposed to a red heat.

457. Silicic Acid Calculi.—I have never met with calculi which contained silica; but Berzelius, Vauquelin, and Fourcroy, and Mr. Venables and others, have detected it. It exists usually in very small quantity only, and in order to obtain it a considerable quantity of the calculus must be operated upon.

458. Prostatic Calculi.—These calculi vary very much in size. The small ones are roundish, but often the sides are more or less flattened when many have been lying in apposition. Small prostatic calculi are represented in Plate XXIV., Fig. 133. They are generally hard and white, like porcelain or alabaster, but occasionally have a soft porous structure. The surface is generally perfectly smooth. They consist of organic material, with phosphate of lime and a trace of carbonate; but it is seldom that triple phosphate is

to be detected. The earthy matter may vary from 50 to 90 per cent.

These calculi are formed in the follicles of the prostrate gland, and commence as minute very transparent concretions, which contain scarcely any hard calcareous material, and at this early period of their formation, therefore, are not entitled to the name of calculi. The microscopic concretions have been detected in the follicles during the periods of youth and early manhood by Mr. Thompson, who states that he found them in every one of a series of fifty prostates which he subjected to examination. In old age, as is well known, they are often found of considerable size. When small, they do not give rise to any symptoms, but they may increase in size and number, and cause the greatest inconvenience and distress.

In sections of the prostate which I have made from a man of about forty years of age, who died from pneumonia, the various stages of growth of these concretions can be observed. The specimen has been preserved in glycerine, in order to increase its transparency. Each follicle of the gland is seen to be occupied with many small roundish bodies, and a considerable number of epithelial particles. Many of the follicles are distended by a number of transparent microscopic concretions, varying from a pale yellow colour to a dark reddish brown. Some of the smallest are not more than the one two-thousandth of an inch in diameter, and yet these are seen to be composed of *several concentric layers*. In the centre of almost all the concretions no one can fail to notice a quantity of minute globules, and in some, one, or more, roundish cells may be seen most distinctly. These, in fact, constitute the "nucleus" of the concretion. The concretions under consideration consist in fact almost entirely of organic matter, which resists the action of moderately strong solution of potash and acetic acid. It is an albuminous material, which, in its chemical characters, agrees with the substance of which the cell wall is composed. The walls of hydatid cysts, and some of the elastic albuminoid concretions occasionally found in the peritoneal cavity, and in other situations, are composed of a substance closely allied to this. These bodies, I believe are formed by the slow deposition of albuminous matter round a nucleus consisting of epithelial cells or *débris*. The material which is deposited in successive layers has probably been formed by the cells of the gland, and is of nearly the same composition as the matter of which the outer

part of the cells themselves consists. It is sometimes colourless, but more commonly of a yellowish colour, and sometimes reddish. A small concretion having been once formed, new matter is deposited upon it, and gradually becomes hardened by the absorption of its fluid constituents.

Up to this period of its formation there is very little earthy matter in the concretion, but gradually a change takes place, and granules of phosphate of lime are precipitated in the substance of the transparent organic matter. This change having commenced, the further separation of calcareous matter goes on. The particles already formed increase by attracting more phosphate from the surrounding fluid, which holds it in solution. As the concretion enlarges, the proportion of phosphatic salts to the organic matter becomes greater, and a *prostatic calculus* at last results. The calculus may attain a very large size, and may even extend forwards, into the urethra, and backwards, into the bladder.

The characters of these concretions are well described by Mr. Henry Thompson, whose remarks are illustrated by careful drawings ("*The Enlarged Prostate*," Plates IV. and V., p. 265). The account above given does not differ materially from the conclusions arrived at by this author, who thinks that the concretions are first formed by the coalescence of the small yellow bodies or granules, which afterwards coalesce and form a larger mass. Professor Quekett considers that they commence by a deposit of earthy matter in the secreting cells of the gland, while Dr. Handfield Jones believes that the concretions originate in a vesicle, which increases by endogenous growth.

In various parts of my sections of the prostate gland, concretions, the nucleus of which appears to consist of granular matter, may be observed. There are others in which concentric layers may be traced quite to a central point or granule. Some have a perfectly transparent centre. And not a few exist, in which the nucleus is composed of small granular cells, varying in number from one to twenty or more ("*Illustrations*," Calculi Plate I., Fig. 4, *b*, *c*). For further information on this interesting subject, I must refer to Mr. Thompson's excellent monograph on "*The Enlarged Prostate*," where the question of diagnosis and treatment are fully discussed.

Summary of the Chemical Characters of Urinary Calculi.

1.—*Calculi which leave only a slight residue after ignition.*

Uric Acid.—Murexide formed when a solution in nitric acid is evaporated and exposed to the vapour of ammonia. A mere trace of residue left after ignition. Ammonia not given off when heated with a solution of caustic potash.

Urate of Ammonia.—Reaction of murexide. Ammonia evolved when heated with potash.

Urate of Soda.—Reaction of murexide. Fuses and gives a yellow tint to the flame. Leaves a decided residue after ignition.

Urate of Lime.—Reaction of murexide. Infusible. After ignition, carbonate of lime remains.

Urate of Magnesia.—Reaction of murexide. Infusible. The residue after ignition dissolves, with slight effervescence, in dilute sulphuric acid. The magnesia is precipitated from this solution, in the form of triple phosphate, upon the addition of phosphate of soda and ammonia.

Xanthine does not exhibit the murexide reaction. The solution in nitric acid turns yellow on evaporation. It is not soluble in carbonate of potassa.

Cystine is soluble in caustic ammonia, and in carbonate of ammonia. It crystallises from an ammoniacal solution in six-sided plates.

Fibrine emits an odour of burnt feathers on ignition. Solution in caustic potash precipitated by acetic acid, and also by ferrocyanide of potassium after the addition of a little acetic acid.

2.—*Calculi which leave a considerable residue after ignition.*

Triple or Ammoniaco-Magnesian Phosphate fuses in the blow-pipe flame, and gives off an ammoniacal odour. It dissolves in acetic acid without effervescence. Ammonia gives in this solution a crystalline precipitate of triple phosphate.

Phosphate of Lime does not fuse. Soluble in hydrochloric acid. Precipitated by ammonia in amorphous granules. From a solution in acetic acid, the lime may be precipitated as oxalate when oxalate of ammonia is added.

Oxalate of Lime.—Soluble in mineral acids, without effervescence. Precipitated from acid solution by ammonia. Insoluble in acetic acid. After ignition, residue effervesces freely on the addition of acids.

Carbonate of Lime.— Soluble in acids, with effervescence. Lime precipitated from an acetic acid solution by oxalate of ammonia.

On the Origin and Formation of Urinary Calculi, and of the Nature of the Nucleus.

459. The Nature of the Nucleus of a Calculus.—This subject has been already referred to incidentally. Whenever there is a tendency to the precipitation of any of the slightly soluble constituents of the urine in an insoluble form before the urine has left the organism, one of the conditions most essential to the formation of calculus is present. If an unusual quantity of any such substance should be formed, so that the urine contains a stronger solution of it than in health, very slight circumstances will lead to its deposition before the urine has left the bladder, and thus insoluble deposits occur. Each little mass of deposit may form a nucleus, around which new matter collects; but, as a general rule, the deposit escapes with the urine. Often it would appear that on the surface, and in the interstices, of rough stones more especially, small quantities of urine are retained, and prevented from mixing with the general mass. Chemical changes soon occur, the immediate result of which is the further precipitation of insoluble material. If the urine alters in its character, different substances may be deposited; thus, oxalate of lime may form the nucleus of the calculus; and, after this has reached a certain size, the deposition of the oxalate may give place to that of uric acid. Again, the precipitation of this substance may cease, and several successive layers of phosphate may afterwards be formed. In some calculi, these layers alternate in a very remarkable manner.

The most interesting part of the whole process is the formation of the nucleus, and it is most important that we should study this matter very carefully. If we were able to ascertain the existence of calculi at a very early period of their formation, we could in many cases, doubtless, promote their expulsion before they attained any size, and thus most distressing suffering would often be prevented, and sometimes the necessity for a severe operation removed.

Any solid matter may form the nucleus of a calculous concretion. Inspissated mucus from any part of the urinary organs—crystals which have been deposited—cells of epithelium—ova of entozoa—pieces of fibrine and small clots of blood—foreign bodies which have been introduced from without, such as peas, portions of slate pencil, or tobacco-pipe, pins and needles, and other substances which are occasionally introduced into the urethra by silly persons. A piece of a catheter and bougie have also been found in the centre of a stone.

My friend Mr. Charles Hawkins gave me, a short time ago, some very curious concretions. They were about half-an-inch in length and about the tenth of an inch in diameter. The surface was rough. They were of a whitish colour, and the calcareous matter of which they consisted was composed of triple phosphate and phosphate of lime. Upon breaking several with care a hair was found in the centre. The patient from whom they were obtained suffered from an ovarian cyst, which opened into the bladder. These concretions were, in fact, composed of earthy phosphates, which had been deposited from the urine upon the hairs, which had doubtless been formed in the ovarian tumour, and had passed into the bladder. Hair and teeth are not uncommonly found in connexion with ovarian tumours.

460. Large Calculi formed by the Aggregation of Smaller ones.—Large calculi are sometimes formed by the aggregation of very small ones, just as a microscopic calculus may be formed by the aggregation of dumb-bells. Mr. Haynes Walton showed me a calculus of an oval form and whitish colour, with a very smooth external surface, about an inch and a half long by an inch wide, which he had removed from the urethra, directly behind the scrotum, of a gentleman of eighty years of age. It had been impacted in this situation for years. There was distinct evidence of the presence of this calculus fifty years before it was removed!

On section, no concretric layers nor central nucleus were seen, but, upon examination with a low power, sections of very small calculi were observed in every part of the surface. In each of these a central nucleus and several concentric lines were clearly distinguishable. These small calculi were connected together by a certain quantity of whitish matter, probably consisting of phosphate of lime and triple phosphate.

461. The Formation of Microscopic Calculi.—I have lately had my attention very forcibly directed to the formation of urinary calculi, in consequence of having met with many specimens of *microscopic calculi* in urine. It is not at all uncommon to meet with microscopic uric acid calculi—aggregations consisting of uric acid crystals, which, if retained, might receive deposits of fresh material on the outside, until the small calculi, varying in size from a mustard-seed to that of a pea, or larger, are formed.

Microscopic calculi of phosphate of lime are by no means uncommon, and are often found in the kidney; but, until a few years ago, I had never had an opportunity of watching the formation of calculi composed of oxalate of lime. The nucleus of these calculi does not consist of mucus or epithelium, as in the phosphatic calculus, but is of the same composition as the exterior. Fig. 125, Plate XXIII., represents a mass of dumb-bell crystals, many of which collections were passed in the urine. Although the mass is seen to consist of a number of distinct crystals, these are firmly attached, so that the whole may be rolled over and over without the individual crystals being separated from each other.

Such collections I have many times seen in the uriniferous tubes in kidneys obtained from *post-mortem* examinations, which leaves no doubt as to the precise seat of formation of these bodies. I have seen them in the kidneys of the fœtus, and have detected dumb-bells in the urine of children under two years of age. Gradually the interstices between the individual crystals become filled up with the same material, and at the same time a few of the larger crystals increase in size at the expense of the small ones. At length a small crystalline mass, of an oval form, is developed, which clearly consists of a microscopic mulberry calculus, and, if retained, will gradually increase in size. (Fig. 124.) When such calculi reach the pelvis of the kidney, a few sometimes increase gradually by the deposition

of oxalate of lime upon their exterior; while, no doubt, the greater number escape with the urine, and give no trouble. Such small bodies would easily become entangled in the mucus of the mucous membrane, and might remain in the pelvis of the kidney without exciting any disturbance until they had grown so large as to cause great inconvenience. If some of them passed down the ureter into the bladder, and happened to be retained for some time in this viscus, in a case where the urine contained much oxalate, they might increase in size until too large to escape by the urethra. It is, therefore, of great importance that cases in which these dumb-bell crystals are deposited should be very carefully watched. This observation is of some interest also as showing the chemical composition of the dumb-bells, which has long been a disputed point.

As I have before stated, many small uric acid calculi, which appear to be composed entirely of this substance, will be found upon careful examination to possess a nucleus consisting of oxalate of lime, and not unfrequently by the action of liquor potassæ well-defined dumb-bell crystals may be obtained. These are insoluble in potash, and also in acetic acid. I have obtained from several specimens fragments of a mass larger than that represented in Fig. 124, and no doubt formed in the same manner. From recent analyses I have made, I have been led to the conclusion that the dumb-bell crystals form the nucleus, around which the uric acid is deposited, more frequently than any other substance. I have not detected oxalate of lime in the centre of the small renal calculi composed of phosphate of lime which I have subjected to examination.

On the Relative Frequency of the Occurrence of the Different Calculi.

462. Frequency of Occurrence of different kinds of Calculi.—It is often very difficult to ascertain why certain varieties of calculi should be found in greater proportion in some parts of the country than in others. The question is one of great interest in connection with the consideration of conditions under which the formation of urinary calculi occurs.

In the collection of calculi at Guy's Hospital the proportion composed of phosphate of lime is as 1:29; at Bartholomew's as 1:32$\frac{1}{4}$; while in Norwich it is as 1:132$\frac{3}{8}$; and in Bristol as 1:155. Of 230

pure uric acid calculi in different hospitals in England and on the continent, as many as 164 are contained in the Norwich collection. (*See* the tables in the appendix to Dr. Prout's work on "*Stomach and Urinary Diseases.*") In the collection of urinary calculi in the museum of Guy's Hospital, it appears, from the statement of Dr. Golding Bird, that out of 208 calculi the *nucleus* consisted of uric acid in 127, of oxalate of lime in 47, of phosphates in 22, and of cystine in 11; or, of uric acid in 60 per cent., of oxalate of lime in 22 per cent., of phosphates in 10 per cent., and of cystine in 5 per cent. These figures are somewhat different to those given by Dr. Golding Bird, because I have thought it more correct to reckon in this calculation 142 calculi, which were obtained from one individual, as one.

Dr. Carter's observations on the composition of the calculi in the Grant Medical College, Bombay, prove that very few *nuclei* are composed of uric acid, while a large number consist of oxalate of lime. The following table, from Dr. Carter's paper, shows the per centage of calculi in India and in England entirely composed of uric acid, urate of ammonia, and oxalate of lime:—

	Grant Med. College. Per Cent.	Coll. of Surgeons. Per Cent.	Guy's Hospital. Per Cent.	Norwich Hospital. Per Cent.
Uric Acid . . .	3·3	32·92	15·38	24·73
Urate of Ammonia	5·0	2·15	3·84	8·29
Oxalate of Lime .	14·0	5·12	9·13	3·16

The following are the conclusions to which Dr. Carter has been led:—" 1. That, in the Bombay Presidency, the proportion of calculi having oxalate of lime for their nucleus, or wholly composed of it, is about twice as great as in England, taking for comparison certain standard collections there. 2. That the proportion of calculi having uric acid or a urate for their nucleus or entire substance, is considerably less in India than in England; in the former, urate of ammonia calculi are somewhat more frequent than uric acid calculi; the opposite is the case in England. 3. That the number of calculi wholly composed of earthy phosphates, or having them for a nucleus, is proportionately much fewer in India than in England, the difference being chiefly owing to the rarity of the mixed phosphate in

the former." (*"An Account of the Calculi contained in the Grant Medical College Museum, with some General Remarks on Calculi in India."* By H. V. Carter, M.D. Lond., Assistant-Surgeon, Acting Curator of the Museum, August, 1859.)

463. Formation of a Calculus composed of Phosphate, Uric Acid, and Oxalate of Lime.—It is, however, important to bear in mind that, in the observations to which I have alluded, the central part of the calculus which is visible to the unaided eye is spoken of as the nucleus, while the real nucleus may be microscopic, and of a different composition to the material which immediately surrounds it. The nucleus of many calculi, which apparently consists of uric acid, is really composed of oxalate of lime, around which the uric acid has been deposited. The phosphatic calculus which is represented in Plate XXIV., Fig. 130, seems to have a nucleus of uric acid about the size of an almond, but the latter contains in its centre a small nucleus consisting of oxalate, which can only be demonstrated by the microscope. Now the history of the formation of this is, probably, as follows:—A number of dumb-bell crystals of oxalate of lime, formed in the uriniferous tubes, became aggregated together, and around this small mass, uric acid was deposited as it lay in the tubes and pelvis of the kidney; then it passed down the ureter into the bladder, where the phosphate was deposited, and where the calculus attained its present size. Now, the deposition of the phosphatic salts on the uric acid is not more dependent on the presence of the latter than the precipitation of the uric acid was consequent upon the presence of the oxalate. In all probability neither the phosphate nor the uric acid would have been precipitated had not the oxalate been present in the first instance. It is not too much to say that, if the latter had not remained for some time in the uriniferous tubes, and gradually increased in size, no calculus would have been formed in the present case; if, therefore, the collection of dumb-bell crystals had been washed out of the kidney by diluents, soon after their formation, the further precipitation of calculous matter would have been entirely prevented.

It is important that we should make numerous observations on the nuclei of various calculi, and endeavour to determine their exact nature by microscopical investigation, and by the application of chemical tests. In this inquiry it will be found advantageous to

take the smallest calculi and examine them as soon as possible after they have been passed. After they have become dry, it is, in most cases, quite useless to attempt investigations on the nature of the nucleus.

The Treatment of Calculous Disorders.

464. On the Importance of the Administration of increased Quantities of Fluids in certain Calculous Affections.—I have already adverted to the importance of increasing the quantity of fluid taken by persons who suffer from certain varieties of urinary deposits. This principle has been fully recognised by Prout and many practical physicians who have had experience in treating cases of this class; but the remedy, perhaps from its very simplicity, has certainly not received the attention at the hands of many practitioners that it deserves. There are conditions of the system which are very much influenced by the dilution of the blood, and many of the chemical decompositions going on are promoted by an increase in the quantity of fluid. Some changes will not take place unless the solutions of the substances be very dilute. Many comparatively insoluble matters are slowly dissolved away by the frequent renewal of the fluid in contact with them.

Even silica is capable of being dissolved in water; and it is from a solution containing so slight a trace, that the substance can only be detected at all by operating upon very large quantities, that the whole of the silicious matter contributing in so important a degree to give firmness to the stems of grasses, is deposited. The amount of water that must pass through the tissues of the plant during its growth, and give up its silicious matter, must be enormous, since the quantity dissolved in each pint of fluid taken up by the roots is so very small.

On the same principle, by causing much liquid to traverse the tissues of a living animal, comparatively insoluble substances may be washed out. It is doubtful if that abundant deposition of urate of soda which is from time to time met with in almost all parts of the body, in certain cases, would have occurred at all, if the fluids had been constantly maintained in a proper state of dilution; and, when these crystals have been deposited, we endeavour to remove them, or prevent further deposition, by diluting the fluids of the body, and by endeavouring to increase the solubility of the urate.

We are, perhaps, too apt, in many chronic cases, to put patients upon a plan of treatment for so short a time as a few days or weeks; and our patients are often unreasonable enough to expect that remedies will remove, in a week, matter which has been slowly accumulating, perhaps, for years. It is chronic cases of this kind which receive such real benefit from the comparatively prolonged course to which they are subjected in a German bath or hydropathic establishment; and it too often happens that, in endeavouring to perform quickly, by remedies, that which it is only possible to effect by giving large quantities of fluid during a considerable period of time, we disappoint ourselves and our patients. Perhaps in the end they attribute to some quack remedy or system, to which they have subsequently had recourse, a favourable result which is really due to the water they have drank with it, and the hygienic rules to which they have been subjected, rather than to the nostrums they have swallowed.

In certain cases of gout, in chronic rheumatism, and in many cases where uric acid and urates are constantly deposited in the urine or in the tissues of the body, the most important of all things is to ensure the thorough washing out of the system. Exercise, when it can be taken, hot baths, Turkish baths, etc., by promoting sweating, excite thirst; and thus more fluid is ingested, which is soon got rid of by various emunctories carrying out with it insoluble substances, the fluid removed being soon replaced by a fresh quantity. In the frequent repetition of these processes from time to time, a vast quantity of fluid is made to pass through the body, with the most beneficial results.

It is surprising how very little fluid some persons take habitually; and this fluid, small as it is, is often saturated with soluble substances. The fluid thus introduced, is, in many persons who live well, barely sufficient to hold the various compounds in solution while undergoing chemical change. Many dislike to drink water, and not a few have a strong prejudice against it; and these are often the very individuals whom we find suffering from gout, rheumatic pains in the muscular and fibrous tissues, and various forms of urinary deposits. They will receive great benefit from moderate sweating, and taking alkalies dissolved in a large quantity of water.

We seldom find difficulty in prevailing on patients to take Seltzer, Vichy, or other alkaline waters daily, although it would be

useless to recommend them to take *pure water*. They can take these waters with their wine at dinner, the last thing at night, and perhaps the first thing in the morning. People who live well, or rather too well, will soon find out that they must continue this plan, and take now and then small doses of alkalies. It is quite superfluous for me to enter into the minute details applicable in individual cases; but I cannot too strongly recommend a careful inquiry into the general habits of patients of this class; for I feel sure that much permanent relief may be afforded by explaining to them the importance of constantly attending to simple rules based on the principles to which I have adverted.

I shall abstain even from enumerating the many drugs that have been recommended in calculous disorders, for I am convinced that we shall practise our profession with greater advantage to our patients, and advance its interests more, by studying carefully the nature of the actual processes going on in disease, and considering how these processes are to be modified by simple means and a few remedies whose action is certain and well understood, than by hunting for new specific medicines, or combining together a great number of compounds, many of which are completely modified as soon as they enter the stomach, and are certainly destroyed long ere they reach the part of the organism where we desire that they should exert their specific influence.

465. On the Methods of Dissolving Urinary Calculi.—I can only offer a very few remarks on this important and interesting subject. Many of the observations which I have made with reference to the prevention or removal of urinary deposits are also applicable to calculi of allied composition. When a uric acid or urate of ammonia calculus, for instance, has been deposited, it may be dissolved, or its increase may be prevented, by producing alterations in the chemical composition of the urine. This may be effected partly by diet, and partly by the administration of various remedies, especially alkalies and the salts of the vegetable acids.

It is possible also, in certain instances, to dissolve the stone by injecting solvents into the bladder. In many cases, however, all our attempts to remove the stone by effecting its solution will be ineffectual, and we shall have to call in the assistance of the surgeon, who may remove the stone entire by lithotomy, or may crush it with the

lithotrite into several small pieces, which escape by the ordinary channel.

Mere dilution of the urine will sometimes exert a considerable influence upon a calculus; and it is possible that some calculi may have been entirely dissolved in this manner. An acid state of urine would tend gradually to dissolve a phosphatic calculus; and it is very possible that, if a feebly alkaline condition of the urine could be maintained for a considerable time, an impression might be made upon calculi composed of different forms of urates, or even upon an uric acid calculus. The irregularities often seen upon the surfaces of such calculi have been very properly termed "water-worn," and clearly indicate that the urine has exerted, for a time at least, a solvent action. Although in certain cases it would undoubtedly be right to adopt for a time treatment of this kind, we must not look forward to the result with any great degree of confidence; at best, such changes are doubtful, tedious, and very uncertain.

Many attempts have been made to dissolve the calculus by injecting fluids, which exert a solvent power upon the stone, into the bladder. The most convenient plan is to inject the fluid through a double catheter for half an hour every two or three days, or more frequently. Dr. Willis has recommended that the fluid should be placed in a reservoir at a sufficient height above the patient, and connected with the catheter by a tube provided with a stop-cock, by which means the flow of the solvent may be carefully regulated. In carrying out this plan, it is very important that the solution should be so weak as to prevent all chance of the mucous membrane of the bladder being injured. Sir Benjamin Brodie showed that phosphatic calculi might be greatly reduced in size, or entirely dissolved, by injecting a weak solution of nitric acid (2 to 2½ minims of strong nitric acid to an ounce of distilled water). Such a solution would also act very favourably in removing the sharp edges of fragments remaining in the bladder after the operation of lithotrity.

The objection to the use of alkalies in attempting to effect the solution of uric acid or urates is, that the phosphates are precipitated from the urine, and the calculus protected from the further action of the solvent.

The most ingenious plan for dissolving calculi was that proposed some years since by Dr. Hoskins, who employed a weak solution of acetate of lead (one grain to the ounce) with a mere trace of free

acetic acid. With a phosphatic stone, double decomposition occurs. Phosphate of lead, in the form of a fine granular precipitate, and an acetate of lime and magnesia, are formed. The solution, it need hardly be said, does not produce any irritation or unfavourable action upon the bladder.

466. Experiments on the Solvent Action of Alkaline Carbonates.—Dr. Roberts found "that very weak solutions of the alkaline carbonates dissolved uric acid calculi with considerable rapidity, while stronger ones altogether failed. In order to decide what strength of solution had the most solvent power, fragments of uric acid, weighing from 40 to 112 grains, were placed in 10-oz. phials, and solutions of carbonate of potash and soda of various strength were passed over them at blood heat. The experiments were continued day and night; and the daily flow of solvent varied from 6 to 15 pints.

"Operating in this way, it was found that above a strength of 120 grains to the pint no solvent action was exerted; and even with 80 grains to the pint there was only a little; but solutions of 50 and 60 grains to the pint dissolved the fragments freely. A coat or crust of white matter invariably invested the stone in the stronger solutions, and prevented further action. At and above 120 grains to the pint this coat was dense and tough, and could not be wholly detached from the subjacent surface. With 80 grains to the pint, it was brittle and easily detached like a layer of whitewash. With 60 grains to the pint and under, either no crust formed at all and the stone dissolved clean with a water-worn appearance, or it was only represented by a few loose flakes, scattered here and there over the surface, and offering no impediment to dissolution. This coating or crust was found essentially to consist of bi-urate of potash or soda, and its formation depended on the fact that the alkaline bi-urates are almost insoluble in any but very weak solutions of the alkaline carbonates. In the strong solutions the bi-urate remains undissolved and encases the stone in an insoluble investment; while in weaker ones it is dissolved as fast as it is formed, the surface of the stone remains clean, and dissolution proceeds without impediment." *

The following table is the result of an experiment continued for forty-eight days.

* "*Archives of Medicine*," Vol. III.

TABLE II.—*Uric Acid and Carbonate of Potash.*

Strength of Solution.	Flow per 24 Hours.	No. of Obs.	Daily Average Loss of Weight per Cent.	Remarks.
Grs. per Pint.	Pints.			
240	6	1	0	Covered with a tenacious white coat, as if of paint.
120	6	3	0	Covered with a less dense coating. After detaching this and wiping, there was a mean loss of weight of 7·1 per cent.
80	6	2	9·8	Covered with a loose detachable white crust.
60	14	2	19·0 ..	Surface clean.
			20·2	
60	6	5	21·4 ..	Loose flakes in spots.
40	6	3	15·6	Sometimes a few loose flakes where the fragment rested.
30	15	4	13·0	
30	8	2	15·0	
30	4	2	9·5 } 11·9	Dissolved clean; occasionally a few loose flakes.
30	6	4	10·2	
20	6	3	11·0	Dissolved clean.
10	6	3	6·5	Ditto.

467.—On Dissolving Calculi by Electrolysis.—Attempts have been made to disintegrate and effect the solution of calculi in the living body by aid of galvanism. MM. Prevost and Dumas ("*Annales de Chèmie,*" Vol. XXIII., p. 202, 1823) employed electricity for the purpose of disintegrating phosphatic calculi, by the mechanical action of the gases set free in the electrolysis of water; but only a grain per hour was thus removed. The *solution* of the calculus was not attempted in those experiments. Dr. Ludwig Melicher ("*Oesterreich. Medicin. Jahrbuch,*" 1848, Vol. I., p. 154) tried to dissolve a calculus by the aid of electricity. It is said that two experiments on the living body were successful. (Quoted by Dr. Bence Jones.)

The latest, as well as the most successful, efforts have been made by Dr. Bence Jones, who employed a solution of nitrate of potash, and decomposed this by the aid of a powerful galvanic battery. The nitric acid set free at the positive electrode would decompose the uric acid exposed to its influence, and the potassa evolved at the negative electrode would dissolve it, so that an uric acid calculus placed between them would be disintegrated at both points. The battery employed was from five to twenty pairs of Grove's plates. From 2 to 9 grains of uric acid calculus were dissolved per hour at the temperature of the body. Of oxalate of lime, ½ grain to 2 grains per hour only were dissolved. The action was four times as slow as upon uric acid calculi. Of oxalate of lime and uric acid, in alternating layers, 4½ to 5 grains were dissolved per hour. Of phosphatic calculi upwards of 25 grains were dissolved per hour.

468. Treatment during the passage of a Calculus along the Ureter.—The violent pain which often, but not invariably, results from the passage of a calculus down the ureter, is generally relieved by hot fomentations or a warm bath. Diluents and sudorifics should be given internally. In one case, referred to by Dr. Prout, the intolerable burning sensation was relieved by the application of pounded ice to the region of the kidney. If there is violent hæmorrhage, the patient must be kept lying down; and if the pain is constant, an opium or henbane suppository in the rectum often affords temporary relief. Moderate exercise, or even the violent jolting of riding, when the suffering is not very great, will often promote the descent of a calculus from the kidney. I know of several cases in which a calculus has passed down the ureter without causing any pain whatever, and the patient was not conscious of its existence until he had passed it. Purgatives, cupping over the loins, and alkaline diuretics, with small doses of opium or henbane, are required, if the descent of the calculus is very slow; or if the stone is impacted in the kidney. Often there is violent sickness, but this is of short duration.

469. Lithotomy and Lithotrity.—This is a part of the subject which I am quite incompetent to discuss, but there are one or two recent modifications in the operation to which I may be permitted to advert very briefly. The operation of lithotomy, which is usually performed by most surgeons in the present day, is the lateral one. For a discussion of the various important points connected with

this operation, I must refer to Professor Fergusson's treatise on "*Practical Surgery*."

Some time since, the median operation was performed with considerable success by Mr. Allarton. Its principal advantages seem to be, that the levator ani and prostatic capsule and plexus escape injury, while the course into the bladder is most direct. There is also the advantage, that the knife is not used either to notch the prostate or to open the bladder. On the other hand, there seems to be considerable chance of injuring the ejaculatory ducts; and a surgical friend tells me that there is a want of space in manipulating with the forceps, and in seizing and extracting the stone, and that there is also some risk, especially in children, of injuring the bulb of the urethra or the rectum. This operation is described in the "*Lancet*," 1859, Vol. I., p. 122. (*See* also Mr. Allarton's work on "*Lithotomy Simplified*." London: Ash and Flint. 1854.)

In connection with the subject of lithotomy, I may remark that, in a recent improvement in the manner of carrying out the lateral operation, by Mr. Wood, the injurious effects which sometimes result from the division of the prostate and levator ani with the knife are altogether avoided. Mr. Wood employs a staff composed of two blades, which can be separated from each other while the instrument is held in position. Dilatation of the urethra is readily effected by allowing the finger to slide in between the blades. In the single case in which this operation has been performed in the living subject, it certainly succeeded admirably. ("*Medical Times and Gazette*," December 22nd, 1860.)

The principal advantages of this over the ordinary lateral and median operations respectively, are, that as the knife does not enter the bladder at all, neither the prostatic veins nor the fascial capsule are injured, nor can the ejaculatory ducts be cut. The levator ani cannot be divided, and all chance of the extravasation of urine into the pelvic areolar tissue is avoided. The form of the external incision is such that more room is given than in the ordinary operation, while injury to all important vessels and other structures is avoided. By this proceeding, the dilatation necessary for the extraction of the stone is much more easily effected than in the median operation.

Of late years, lithotrity appears to have been carried out very successfully in numerous cases in which the operation of lithotomy

would have been practised formerly. The number of fatal cases resulting from lithotomy is considerably greater than that obtained from an analysis of the cases of lithotrity to which I have been able to refer. And it appears that stones of very large size may be crushed with safety. So far as I can learn, setting aside a few exceptional cases, it would seem that lithotomy afforded but a poor chance of safety where lithotrity could not be confidently recommended. These remarks, I need hardly say, apply only to adults. In children, lithotomy is so safe an operation, while the small size of the urethra and other circumstances are unfavourable to lithotrity, that it is not likely that surgeons will have recourse to any other proceeding.

The experience especially of Sir Benjamin Brodie, Mr. Charles Hawkins, and Mr. Prescott Hewett, has proved that, when performed with care, lithotrity is a most successful operation. Mr. Hawkins tells me that he has operated with success even in cases of stricture and irritable bladder, and has performed lithotrity where lithotomy could not have been undertaken. (*See* a case reported in the "*Transactions*" of the Royal Medical and Chirurgical Society for 1859.) On the subject of lithotrity, I must refer to Sir B. Brodie's paper in the twentieth Volume of the "*Transactions*" of the Royal Medical and Chirurgical Society, in the concluding paragraph of which are these words—"My own experience has certainly led me to the conclusion that lithotrity, if prudently and carefully performed, with a due attention to minute circumstances, is liable to a smaller objection than almost any other of the capital operations of surgery."

Brief Summary of the Principal Constituents of Urine, and their Microscopical and Chemical Characters.

Healthy Urine. Quantity.—A healthy man usually passes from 40 to 60 oz. (17,500 to 26,250 grains) during twenty-four hours.

Quantity of Water.—Average, about 20,000 grs. in twenty-four hours, or 940 grains per 1,000 grains of urine. Varies much even in health, and at different periods of the day.

Quantity of Solid Matter varies inversely as the water—600 to 1,200 grains excreted in twenty-four hours.

Specific Gravity of the urine in health varies from 1,015 to 1,025; depends not only upon the quantity of solid matter in the urine, but also upon the specific gravity of the constituents. (§ 117.)

Reaction.—Acid. Varies at different periods of the day. (§ 119.)

On the quantities of the various constituents in the urine in health, *see* Chapters VI., VIII., and the table on p. 136.

Examination of Urine.—When endeavouring to ascertain if there be any abnormal condition of the urine, note its *reaction*, *the quantity* passed in twenty-four hours, its *specific gravity*, and the *amount of solid matter*. Also apply certain chemical tests, and resort to microscopical examination, if there be any deposit. (Chapter V.)

Chemical Analysis alone will show the presence of urea, uric acid, extractive matters, salts, sugar, albumen, bile; and is employed for ascertaining the composition of certain deposits. (Chapters VI., XI., XII.)

The Microscope discovers various substances which are either not recognised at all, or are with great difficulty proved to be present by other means. (Chapter III.)

Directions for instituting a rough general Examination of a Specimen of Urine.

The most necessary tests may be arranged under six heads; and, by having recourse to one or more of these, we are enabled to determine roughly the most common morbid states of the urine.

1. **Reaction** (§§ 118, 119, 120).

2. **Specific Gravity** (§ 117).—When very high, we may suspect an increased quantity of urea (excess); or the presence of sugar. Apply tests mentioned on p. 408. Hysterical urine, and urine of cases where much water has been taken, is of very low specific gravity.

3. **Heat.**—Urate of soda, distinguished from pus or phosphate (§ 374). Albumen. Precipitation of phosphate, &c. (§ 244).

4. **Nitric Acid** dissolves phosphates (§ 245); decomposes urate of soda (if strong, rapidly); precipitates albumen in urine, even when in very small quantity and due to the presence of pus. Used also to test the presence of uric acid (§ 137). Excess of urea (§ 206). Bile (§ 263).

5. **Potash.**—Urates, distinguished from pus or phosphate (§ 374). Uric acid, from blood. Sugar indicated by a brown colour, after prolonged boiling.

6. **Nitrate of Silver.**—Precipitate of chloride of silver, insoluble in nitric acid (§ 175). In certain cases, the urine does not contain a trace of chloride of sodium (§ 220).

Chemical Examination of Urine.

1.—*Chemical Examination with reference to Detecting the Nature of the Deposit.*

a. **Light and Flocculent Deposits** (Chapter XIV., p 289).—Deposits of this class are generally too light, and the quantity is too small, for the application of chemical tests. (See "*Microscopical Examination of Deposits*, p. 424.)

b. **Dense and Opaque Deposits** (Chapter XV., p. 313), usually present in considerable quantity, are of three kinds, which much resemble each other in appearance.

1. **Urate of Soda** (§ 375).—Lateritious, nut-brown sediment. Varies much in colour. Urine acid. *Tests.*—Soluble by heat, in potash, ammonia, water. Decomposed by acid; uric acid set free.
2. **Phosphates** (§ 388).—Urine usually alkaline or neutral. When triple phosphate alone is present, the urine is sometimes feebly acid. *Tests.*—Insoluble by heat or in alkalies; soluble in acids, and afterwards precipitated by ammonia.
3. **Pus** (§ 381).—Diffused through the urine, rendering it turbid, or forming a bulky creamy deposit, with clear or tubid supernatant fluid. *Tests.*—Rendered glairy by potash. Albumen in urine precipitated by heat and by nitric acid. *Caution.*—Albumen *may* be independent of the pus.

c. **Crystalline or Granular Deposits are usually in small quantity, forming a sediment which may either be coloured or transparent and colourless.**—(Chapter XVI., p. 337.)

1. **Uric Acid** (§ 397).—Colour characteristic, usually of a dark mahogany brown, sometimes paler, very seldom quite colourless. Large separate clusters of crystals. It rarely forms a granular deposit. *Tests.*—(§ 398).—Soluble in potash, nitric acid. After evaporation with nitric acid, ammonia gives the dark violet colour of murexide or purpurate of ammonia. Often mixed with blood, smoky urine. Albumen detected in the fluid.
2. **Blood-corpuscles** (§ 416).—See "*Microscopical Examination.*"
3. **Oxalate of Lime** (§ 402).—Seldom in sufficient quantity to form a deposit visible to the unaided eye. *Tests* (§ 408).—

Insoluble in water, potash, and acetic acid, even when boiled; soluble in mineral acids; and again thrown down amorphous, but unchanged in composition, by ammonia. By incineration, an odour like that of burnt feathers is evolved. Black ash becomes white by decarbonisation; this ash is soluble in acetic acid, with copious effervescence. Oxalate of ammonia added to acetic acid solution precipitates oxalate of lime.

4. **Silica** (§ 415) is said to have been found in very minute quantities in urine; rarely met with as a deposit, except in the form of grains of sand in the urine of hysterical patients and impostors. Easily known by its great density, general appearance, and insolubility in strong mineral acids.

2.—*Chemical Examination with reference to the Discovery of an Abnormal Condition of the Soluble Constituents of the Urine, or of the existence of Substances of a Soluble Form not met with in Health.* (Chapter XI.)

1. **Albumen** (§ 240 *et seq.*).—Urine pale; often of very low specific gravity, 1,005 to 1,012 or 1,014. Heat or nitric acid, if urine be acid; nitric acid, if the urine be alkaline. Reason: solubility of albumen in alkalies. *Fallacies.*—A *trace of nitric acid* prevents the precipitation of albumen by heat (248). Precipitation of phosphates by simply boiling the urine. Precipitation of minute crystals of uric acid upon the addition of dilute nitric acid to some specimens of urine: hence necessity for employing both tests (§ 246).

2. **Excess of Urea** (§ 206).—Urine frequently high coloured; specific gravity, 1,030 to 1,040. Upon the addition of an equal volume of strong nitric acid, crystals occur within half-an-hour, if there be much excess. Oxalic acid is often employed when the urea is to be determined quantitatively.

3. **Sugar** (§ 274).—Urine pale, of high specific gravity, from 1,030 to 1,050. Trommer's test (§ 277). Potash tests (§ 276). Fermentation test (§ 283). Tartrate of copper (§ 278).

4. **Sulphates** (§§ 169, 224).—Nitrate of barytes or chloride of barium, after the addition of a few drops of nitric acid.

5. **Chloride of Sodium** (§§ 173, 220).—Nitrate of silver, after the addition of a few drops of nitric acid.

6. **Bile** (§§ 258, 259, 263, 264).—Urine of a dark yellow colour. Nitric acid; play of colours. Pettenkoffer's test.

Microscopical Examination of Urinary Deposits.
(Chapter III.)

Great caution required in every step (p. 25). A large quantity of urine (at least four ounces) should be allowed to subside in a *conical glass* (Figs. 6, 9, Plates I., II.) for some (two or three) hours, or the greater portion of the urine may be poured off from the deposit, which may then be submitted to examination. In the last case, small bottles only need be taken to collect specimens; but, of course, no idea can be formed as to the relative amount of deposit present (§ 52). *Pipettes* (Fig. 14, Plate III.). *Examination in cells or cages* (Figs. 24, 25, 26, Plate V.).

Insoluble matter may be—

1. Diffused through the urine, or it may form a visible deposit. When the insoluble matter has subsided, the deposit may assume one of three characters (Chapter XIV.).
2. It may occupy a large bulk, and present a flocculent appearance; or
3. It may form a dense, opaque, and abundant or scanty stratum; or
4. The deposit may be small in quantity, crystalline, consisting of sparkling colourless points, or of more or less coloured granules.

All these characters may coexist in one deposit, in which case we observe three distinct strata, each of which must be *separately* submitted to microscopical examination. In many cases there are two distinct strata.

1. *Substances floating on the Surface of the Urine, or diffused through it, but not forming a visible Deposit.*
(Chapter XIV., p. 290.)

a. Opalescence produced by urates (p. 290).
b. Opalescence produced by vibriones (§ 325).
c. Milk in urine (§ 325).
d. Chylous urine (§ 327).

2. *Deposit light and flocculent, occupying a considerable Bulk.*
(Chapter XIV.)

Always take specimens from the bottom of the glass for examination, as well as from the bulk of the deposit.

a. Simple mucus-corpuscles (§ 344), or with bladder or renal epithelium (§ 353). Cells sometimes tinged with yellow bile (§ 262).

b. Simple mucus, or epithelium with numerous small crystals of oxalate of lime entangled in it (p. 293).

c. *Casts.* Various forms of casts (§ 363 *et seq.*) *α.* Casts of medium diameter. *β.* Casts of considerable diameter. *γ.* Casts of small diameter.

d. Spermatozoa (§ 358). Vibriones (§ 349). Torulæ (§ 350). Sarcinæ (§ 351).

e. Matters of extraneous origin (§ 78). Bed-flock: hair: feathers: dust. Distinction from casts, &c. (§ 84).

3. *Deposit dense, opaque, and abundant.* (Chapter XV.)

a. Urates. Amorphous deposit.

b. Pus (§ 381). Characters. Potash. Acetic acid.

c. Phosphates (§ 388). Phosphate of lime (amorphous) (§ 390). Triple or ammoniaco-magnesian phosphate (crystalline) (§ 387). Mixed with carbonate or oxalates.

d. Matters of extraneous origin (§ 78). Sand. Starch: potato: rice: bread-crumbs: arrowroot (§ 85).

4. *Granular or Crystalline Deposits, small in Quantity, sinking to the Bottom, or adhering to the Sides of the Vessel.* (Chapter XVI.)

a. Uric acid (§ 396). Forms of. Amorphous. Varies much in colour. Polarisation.

b. Oxalate of lime (§ 402). Forms of. Dumb-bells (§ 404). Distinction of oxalate of lime from triple phosphate.

c. Phosphate of lime (§ 390). Phosphate of lime, radiating crystals (§ 392).

d. Blood-globules (§ 416).

e. Cystine (§ 411). Carbonate of lime (§ 414).

f. Matters of extraneous origin (§ 78).

TABLES
FOR
THE SYSTEMATIC QUALITATIVE EXAMINATION OF URINE.

*** ALL who desire to become practically familiar with the most important characters of the urine, are strongly recommended to submit to the routine which a conscientious practice of the experiments given in the following tables necessarily involves. The author is fully persuaded that the patient prosecution of the course recommended, for two hours on eight or ten occasions, will enable the practitioner to obtain a practical familiarity with the subject, which it is impossible he can acquire by reading.

TABLE I.

GENERAL CHARACTERS OF URINE (Chapter V.).

*** The works referred to in these Tables are the present one, and the "*Illustrations of Urine, Urinary Deposits, and Calculi.*"

Place about 100 grains of urine in a basin to evaporate over the water-bath.

1. COLOUR, SMELL, CLEARNESS OR TURBIDITY, DEPOSIT, FILM ON SURFACE.—Pour about four ounces of urine into a test-glass; take notice of its **colour** (§ 112) and **smell** (§ 113). Observe whether the specimen be **clear** or **turbid**, and notice the faint **mucous cloud** which collects on standing (§ 116). Observe whether there be any **deposit** which sinks to the bottom of the vessel, or **film** floating upon the surface of the fluid (§ 324, p. 289).

2. SPECIFIC GRAVITY.—Take the **specific gravity** of the urine (§ 117).
   α. Using the *urinometer* (§ 117, Fig. 6, Plate I.; Fig. 15, Plate III.).
   β. Using the *specific gravity bottle* (§ 117, Fig. 16, Plate III.).

3. REACTION.—Test the urine with *blue litmus* paper. 2. If the specimen exhibit no **acid reaction**, test it with *reddened litmus*, and observe whether the colour be restored upon gently warming the paper upon a strip of glass, **volatile alkali** (§ 121), or not, **fixed alkali** (§ 122).

4. CRYSTALLINE SUBSTANCES IN URINE.—Place a drop of urine which has been *concentrated by evaporation* upon a glass slide, and cover it with thin glass. When cool, examine it

under the microscope; note the form of crystals present, **urate of soda** (§ 213), **acid phosphate of soda** (§ 156), **basic phosphate of soda** (§ 157), **sulphate of soda** (§ 169), **chloride of sodium and urea** (§§ 129, 173), **ammoniaco-magnesian or triple phosphate** (§ 164), **granules of phosphate of lime** (§ 162). ("*Illustrations*," *Urine*, Plate I.)

5. DECOMPOSITION BY HEAT.—Place a small portion of the *solid residue* (about the size of a pin's head) in a hard glass tube, and expose it to the flame of a spirit-lamp, gradually raising the temperature to redness. Test the *reaction* of the vapour emitted from the tube with reddened litmus paper, which has been moistened. Ammonia evolved (§ 152).

6. SALINE CONSTITUENTS.—Remove the *carbonaceous residue* from the tube, and expose it upon platinum foil to a dull red heat, until nothing but a **white ash** remains (§ 151, "*Illustrations*," *Urine*, Fig. 2, Plate I.).

7. ALKALINE SALTS.—Place the ash upon a glass slide, and treat it with one drop of *distilled water*, applying warmth. Concentrate the aqueous solution by evaporation, and allow crystals to form. These should be covered with thin glass, and subjected to microscopical examination. **Chloride of sodium** (§ 173), **phosphate of soda** (§ 155), **sulphates of soda and potash** (§ 169). ("*Illustrations*," *Urine*, Plate I., Fig. 1).

8. EARTHY SALTS.—If the saline residue is not entirely dissolved by water, add a drop of nitric acid, and observe whether in effervescence **carbonate of lime** occurs, or if the *insoluble matter* is dissolved without the escape of any *bubbles of gas*, **phosphate of lime.**

9. URIC ACID.—Place about four ounces of urine in a beaker, add about a drachm of *hydrochloric acid*, and allow the mixture to stand for twelve hours. **Crystals of uric or lithic acid** (§ 137).

10. URIC ACID.—To a small quantity of the urine, concentrated by evaporation, and placed in a watch-glass, add a few drops of *acetic acid*, and insert in the mixture a few *filaments of tow or silk.* Allow the whole to stand for twenty-four hours, covered with a glass shade, in order to prevent the entrance of dust (§ 137, 3). **Crystals of uric or lithic acid.**

*** The deposits from the urine examined in §§ 9 and 10 are to be examined in Table II.

TABLE II.

SYSTEMATIC QUALITATIVE EXAMINATION (Page 104).

THE ORGANIC CONSTITUENTS (Chapter V., p. 71).

11. REACTION.—SPECIFIC GRAVITY.—Ascertain the **reaction** and **specific gravity** of the specimen of urine, and note any general characters you may observe (Chapter V.).

12. PLACE two portions, A and B, of about 300 grains each, in basins, to evaporate over the water-bath (§ 151, Figs. 3, 8, Plate I.).

13. IN PORTION A.—UREA, MUCUS, URIC ACID, EXTRACTIVE MATTERS, EARTHY PHOSPHATE, AND SILICA (§ 151).

14. IN PORTION B.—FIXED SALTS (Chapter VI.).

B is to be placed in a *platinum capsule* and incinerated (Fig. 5, Plate I., § 9). The saline residue is to be maintained at a red heat, and, when decarbonized, is to be preserved for examination in Table III. Proceed with Portion A.

15. UREA.—$C_2H_4N_2O_2$. Extract A is to be treated with three successive portions of *Alcohol*, about the *sp. gr.* ·825, which are to be boiled upon the residue for a few minutes over the *water-bath*. The alcoholic solutions are to be mixed together and concentrated by evaporation. The extract is to be treated with a little *water*, in order that it may be reduced to the consistence of *syrup* (§§ 126, 151).

a. A little of the syrupy extract, when cold, is to be placed in a small basin, and treated with a few drops of strong *Nitric Acid*, **nitrate of urea** $C_2H_4N_2O_2,HO,NO_5$. Examine the crystals thus formed in the microscope (§ 151, ("*Illustrations*," *Urine*, Plate III.).

b. The remainder of the concentrated extract is to be placed over a *water-bath*, conveniently arranged, and treated with *crystals* of *oxalic acid* until no more are dissolved at a temperature of 200°. The mixture is then permitted to cool; and, after the crystals have been slightly washed with a little distilled water, they may be placed between folds of filtering paper, **oxalate of urea**, $C_2H_4N_2O_2, HO,C_2O_3$. Examine a few of the crystals in the microscope ("*Illustrations*," *Urine*, Plate IV.). After having been well pressed, to absorb **extractive matters**, &c., the crystals are to be dissolved *in warm water*, and excess of **carbonate of lime** added to the solution, to decompose the **oxalate of urea**. When the mixture becomes *neutral* to *test paper*, it is to be filtered, and the clear solution, which

consists of **urea,** with a little colouring matter, concentrated by evaporation. **Urea and colouring matter** remain. The latter may be removed by dissolving the urea in water, and boiling the solution with animal charcoal, and subsequent filtration (§ 151).

The process of filtering is seen in Fig. 13, Plate III.; the manner in which the paper is folded, in Fig. 12, Plate II. The wash-bottle, for washing precipitates, is represented in Fig. 10.

16. Mucus, Lithic Acid, Earthy Phosphate, and Silica.—*The matter insoluble in Alcohol,* D (§ 151), is to be treated with hot water, to dissolve extractive matter, and filtered.

The residue on the filter is to be dried, and incinerated on platinum foil. The **mucus** and **uric acid** are destroyed.

When the residue, consisting of **phosphate of lime** and **silica** is decarbonized, it is to be treated with a drop of *nitric acid.* Observe whether effervescence occurs, **carbonate of lime** CaO,CO_2. A trace of **silica** remains undissolved (§ 151).

To the acid solution add a drop of *ammonia,* and note the result. Examine the precipitate in the microscope, and notice the crystals of **ammoniaco-magnesian or triple phosphate,** and the amorphous granules of **phosphate of lime** (§ 162). ("*Illustrations,*" *Urinary Deposits,* Plate IX., Figs. 1, 2; Plate XXI., Fig. 4).

17. Uric Acid $C_{10}H_4N_4O_6$.—Examine the crystals deposited upon the sides of the vessel, and upon the filamants of *tow* or *silk* which were set aside in Table I., with the microscope, and note the form of the crystals (Fig. 57, Plate XI.; Figs. 105, 106, Plate XX., "*Illustrations,*" *Urinary Deposits,* Plates V., VI., VII., VIII.). Then collect them upon a *glass slide,* and divide them into three portions.

a. To the **first** add a little *solution of potash,* which dissolves the crystals, forming **urate of potash,** and afterwards excess of *acetic* $C_4H_3O_3,HO$, or *hydrochloric acid,* HCl. After a few minutes have elapsed, subject the deposit to microscopical examination. *Crystals of* **lythic or uric acid** $C_{10}H_4N_4O_6$ (§ 137, 2, 3).

b. To the **second** portion add a drop of *nitric acid* HO,NO_5, evaporate the mass to dryness over the lamp, then allow it to cool, and add a little *ammonia* NH_3, or expose the acid residue to the vapour of ammonia. A beautiful purple colour, owing to the formation of **murexide** $C_{12}N_5H_6O_8$ results (§ 137, 1; § 398).

c. To the **third** portion add solution of *carbonate of potash* KO,CO_2+2Aq, which will dissolve the uric acid $C_{10}H_4N_4O_6$, but more slowly.

TABLE III.

SYSTEMATIC QUALITATIVE EXAMINATION (§ 183).

THE SALINE CONSTITUENTS (Chapter VII.).

18. ALKALINE AND EARTHY SALTS.—Treat the residue resulting from the incineration of portion B in Dem. II. with boiling distilled water and filter (§ 183); reserve the residue for subsequent operations (No. 23, below). Proceed with the *clear solution*, which is to be divided into two parts, one consisting of *three-fourths* and the other of *one-fourth.*

The *fourth part* of the solution is to be divided into three *equal portions* (No. 21).

ALKALINE SALTS.

19. SULPHURIC ACID.—To about three-fourths of the clear solution add a few drops of *nitric acid*, HO,NO_5, and observe if *effervescence* occurs, **carbonate of soda** NaO,CO_2+10Aq. Next add to the solution, placed in a flask and heated over a lamp, a small quantity of a solution of *chloride of barium*, $BaCl+2Aq$. Boil the mixture and separate the precipitate by filtration. **Sulphate of baryta,** BaO,SO_3 (§ 169).

While filtration is proceeding, pass on to No. 21.

a. A small quantity of the white precipitate of **sulphate of baryta** is to be boiled in *caustic potash*, and another portion in strong *nitric acid*. It is insoluble in both.

20. PHOSPHORIC ACID.—The solution filtered from the precipitate produced by *chloride of barium* is to be treated with excess of *ammonia* NH_3 and the mixture rapidly filtered, *avoiding exposure to air* as much as possible. **Phosphate of baryta** $_2BaO,HO,PO_5$ (§ 168, 183).—*Concentrate* the clear solution by evaporation, and when reduced to a small bulk continue its further examination (No. 22).

21. CHLORINE, PHOSPHORIC ACID.—To the *first portion* add a few drops of *nitric acid* and excess of a solution of *nitrate of silver* AgO,NO_5, **chloride of silver** $AgCl$ (§ 175). Filter. To the solution carefully add *ammonia*, avoiding an excess, **phosphate of silver** $3AgO,PO_5$. Then add more *ammonia*, and afterwards *nitric acid* (§ 183).

Phosphate of silver is soluble in *ammonia* and also in *nitric acid.*

Chloride of silver is soluble in *ammonia*, but insoluble in *nitric acid.*

a. Phosphoric Acid *of the alkaline phosphates precipitated as* **ammoniaco-magnesian** or **triple phosphate.** To the *second* portion add a little of a solution of *muriate of ammonia* NH_4Cl, *ammonia* NH_3, and *sulphate of magnesia* MgO,SO_3. A precipitate of **phosphate of ammonia and magnesia** will take place, $_2MgO,NH_4O,PO_5$. This is insoluble in *ammoniacal salts* (§ 164).

b. Phosphoric Acid *of the alkaline phosphate precipitated as* **phosphate of lime.** To the *third* portion of the clear solution add a little of a solution of *chloride of calcium* $CaCl$, and *ammonia* NH_3. **Phosphate of lime** $_2CaO,HO,PO_5$ is precipated.

Allow the two last precipitates to subside, and then remove a little with the pipette and subject them to microscopical examination. Phosphate of lime is amorphous, but the ammoniaco-magnesian phosphate is crystalline (§ 166). ("*Illustrations of Urinary Deposits,*" Plate IX., Figs. 1, 2; XXI., Fig. 4.)

22. Potash, Soda.—Return to the examination of the solution obtained in No. 20, in which the presence of **potash** KO and **soda** NaO is to be demonstrated. Add it to an excess of *ammonia* NH_3, and carbonate of ammonia $2NH_4O,3CO_2$, in order to precipitate the excess of *baryta* BaO. Filter. Evaporate the solution to *dryness* and gently ignite the residue in a *platinum capsule.* Dissolve what remains in water, and add a few drops of solution of *bichloride of platinum* $PtCl_2$. Evaporate the mixture to dryness over the water bath (p. 128).

The *dry residue* is to be treated with successive portions of *alcohol.* **Potassio-chloride of platinum** $KCl,PtCl_2$ remains undissolved (p. 128).

The *alcoholic solution* is to be concentrated that crystals may form, **sodio-chloride of platinum** $NaCl,PtCl_2$. Examine both the crystalline deposits in the *microscope* under the influence of polarised light.

The crystals of potassio-chloride of platinum are *octohedral* and *do not* polarise, while the crystals of sodio-chloride of platinum are *acicular*, and *do* polarise.

EARTHY SALTS.

23. Phosphate of Lime, Phosphate of Ammonia and Magnesia.—Return to the examination of that portion of the saline residue insoluble in water (No. 18).

Add a few drops of *nitric acid* NO_5 to the residue, and notice if *effervescence* takes place, **carbonate of lime** CaO,CO_2. Dilute the solution and filter. Reserve any insoluble matter for further operations (No. 24).

a. To one portion of the clear solution add excess of

ammonia NH_3, and examine the precipitate in the microscope. **Phosphate of lime** $8CaO,3PO_5$, **and phosphate of ammonia and magnesia** $2MgO,NH_4O,PO_5+12Aq$ (§ 164).

b. LIME, MAGNESIA.—To another portion of the acid solution add *ammonia* NH_3, and afterwards excess of acetic acid $C_4H_3O_3,HO$, and then *oxalate of ammonia* NH_4O,C_2O_3+Aq, **oxalate of lime** CaO,C_2O_3. Boil and filter (p. 127).

Concentrate the clear solution by evaporation. When cold, add a little solution of *chloride of ammonium* NH_4Cl, and phosphate of soda $_2NaO,HO,PO_5+24Aq$. Well stir the mixture, and examine the crystalline deposit in the microscope. **Triple or ammoniaco-magnesian phosphate** $2MgO,NH_4O,PO_5+12Aq$. ("*Illustrations of Urinary Deposits*", Plate IX., figs. 1, 2.)

24. SILICA.—That portion of the *earthy salts* insoluble in water is to be boiled with a few drops of strong *nitric acid*, HO,NO_5, silica, SiO_3 remains undissolved (p. 127).

IN THE SYSTEMATIC QUALITATIVE EXAMINATION OF HEALTHY URINE, commenced in Table II., the presence of the following substances has been demonstrated:—

In portion A,

Urea	**Mucus**	**Earthy phosphates**
Uric acid	**Extractive matters**	**Silica**

In portion B,

Chlorine	**Potash**	**Magnesia**
Sulphuric acid	**Soda**	**Silica**
Phosphoric acid	**Lime**	

See also forms in pp. 106 and 129.

TABLE IV.

SUBSTANCES HELD IN SOLUTION IN MORBID URINE
(Chapters IX., XI., XII.).

EXCESS OF UREA, ALBUMEN, BILE.

25. ASCERTAIN the *reaction* and *specific gravity* of the specimens of Urine marked A, B, C, D.

26. ALBUMEN.—Boil a portion of the urine in a test-tube over a *spirit lamp* and observe the character of the precipitate, if one is formed.

a. Treat a **second** portion with about ten drops of nitric acid (§ 241).

If no precipitate is produced upon the addition of nitric acid, or upon the application of heat, pass on to No. 27.

b. A **third** portion to be treated with half its bulk of *strong nitric acid*, and boiled.

c. To a **fourth** portion add two drops of very *dilute nitric acid*, and afterwards boil.

A very dilute solution of nitric acid prevents the precipitation of albumen by heat (§ 248).

d. A **fifth** portion is to be treated with a little *acetic acid* $HO,C_4H_3O_3$, and afterwards a solution of *ferrocyanide of potassium* $K_2,FeCy_3+3Aq$ is to be added (p. 138).

e. To a **sixth** portion add a solution of *bichloride of mercury* $HgCl_2$ (§ 250).

27. EXCESS OF UREA $C_2H_4N_2O_2$.—Add to the specimen of urine suspected to contain excess of *urea* from its deep colour and high specific gravity, about half its bulk of *nitric acid* HO,NO_5. Allow it to stand for a few minutes, and examine the crystalline deposit which forms in the microscope, **nitrate of urea,** $C_2H_4N_2O_2,NO_5$ (§ 206).

28. SUGAR.—*a.* A **portion** of the urine suspected to contain sugar is to be boiled in a test tube with half its bulk of solution of *potash* KO,HO (*Moore's test*). If it becomes of a dark reddish brown colour from the formation of *melassic* or *sacchulmic acid*, it is to be treated with excess of *nitric acid*, when the peculiar odour resembling that of *molasses* will be produced, and the dark brown solution will become perfectly clear (§ 276).

b. **A second portion** is to be treated with one or two drops of a solution of *sulphate of copper* $CuO,SO_3+5Aq.$, and afterwards a considerable excess of *potash* KO,HO is to be added. The *dark blue solution* is then to be heated over the spirit-lamp and boiled for a moment, when a yellowish brown **precipitate** of *suboxide of copper* Cu_2O, will be produced [*Trommer's test*] (§ 277).

c. A **third portion** is to be heated with about an equal bulk of the solution of *tartrate of copper* in *potash*, **Barreswil's solution** (§ 278).

d. **Fermentation.**—Fill one of the tubes placed on the table with urine, and the other with water, to each add six drops of *yeast*, and then a little more urine and water, in order that the fluids may rise above the brim of the tubes. Apply the *india-rubber pad*, and invert them in the small beakers. Remove the india-rubber, and add some mercury. Place the whole in a temperature of 80°, and, after the lapse of two hours, compare the size of the bubbles of gas in the respective tubes (§ 283).

e. **Crystals.**—Allow a few drops of diabetic urine to evaporate spontaneously upon a glass slide, and examine the residue on the next day to see if crystals have formed (§ 274, Plate XIII., Fig. 66).

29. **Bile.**—*a.* One portion of the urine is to be placed in a test-tube, and after the addition of one drop of *syrup*, two-thirds of its bulk of strong *sulphuric acid* SO_3HO are to be added *cautiously by drops.* Shake the mixture, and allow it to stand for a few minutes. If sufficient heat is not produced by the addition of the acid, warm the tube slightly over the lamp. The mixture becomes of a *dark violet colour*, which, however, is destroyed by a temperature a little above 140° [*Pettenkofer's test*] (p. 144).

b. Pour a few drops upon a *clean white plate*, and after spreading it over the surface, allow a drop of *nitric acid* to fall in the centre. Observe the **play of colours** (§ 258 *a*).

c. To another portion add a few drops of *serum*, and, after agitation, a little *nitric acid* NO_5,HO. Observe the colour of the coagulated albumen [*Heller's test*] (§ 259).

TABLE V.

CHEMICAL EXAMINATION OF URINARY DEPOSITS.

III.—SECOND CLASS OF URINARY DEPOSITS (Chapter XV.)

PUS, URATES, PHOSPHATES.

30. **Observe** the characters of the urinary deposits in the glasses A, B, C, and note the *colour, reaction*, and *specific gravity* of each specimen.

31. **After** having poured off the *supernatant fluid*, take about *one-fourth* of the *deposit* from each glass, and pour it into a test-tube. Add to it about half its bulk of *solution of potash* KO,HO.

Pus is rendered *transparent, viscid*, and *glairy* by *potash* (§ 374).

Urates dissolved by *potash*. Solution *clear* and *limpid*.

Phosphates are not affected by *potash*.

32. Urates or Lithates.—If the deposit be soluble in *potash* KO, and is not rendered *glairy*, take another portion and heat it in a clean test-tube with a little water. It will be *dissolved* upon the application of a *gentle heat*, and will be *precipitated* again when the solution becomes *cool*. Another portion may be dissolved in *potash* KO, and then excess of hydrochloric acid HCl, or ascetic acid $C_4H_3O_3$,HO, added. After the lapse of *ten* or *twelve hours* the deposit, consisting of **uric acid** $C_{10}H_4N_4O_6$, may be subjected to *microscopical examination*, or tested in the manner described in No. 17, *a, b* (§ 137).

33. Pus.—If the deposit be rendered *glairy* by *potash* KO, note carefully its *microscopical characters* under the quarter of an inch object glass, and then add a drop of *acetic acid* $C_4H_3O_3$,HO, and observe the change which takes place in the appearance of the corpuscles. Notice if any crystals of *triple phosphate* $_2MgO,NH_4O,PO_5 + 12Aq$. are present in the deposit, and observe the character of any *epithelium* that may be met with (§§ 383, 384).

A small portion of the supernatant fluid is to be treated with *nitric acid* HO,NO_5, and another portion boiled in a test-tube. The precipitates consist of **albumen** (§ 383).

34. Earthy Phosphates.—If the deposit consists of earthy phosphates, it will not be altered by *potash* KO, nor by the *application of heat*. A portion of it is to be treated with *nitric acid* HO,NO_5, in which it is soluble without

effervescence.* Observe its microscopical characters (§ 246). If there are no well-defined crystals dissolve a portion in dilute *nitric acid*, and then add excess of *ammonia*. Upon microscopical examination, the precipitate will be found to consist of feathery crystals of **triple phosphate** and granules of **phosphate of lime** (§§ 164, 388).

IV.—THIRD CLASS OF URINARY DEPOSITS.
(Chapter XVI.)

URIC OR LITHIC ACID, OXALATE OF LIME, SAND.

35. Observe the character of the *deposits* in the glasses D, E, F, and note the *colour*, *reaction*, and *specific gravity* of the fluid in each case.

36. If the Deposit is very small in quantity, remove it in the manner described in §§ 54, 55, and place it in a small watch-glass or in the cell (Plate V., Fig. 25).

Uric or lithic acid is dissolved by *potash*, while **oxalate of lime** and **sand** are not affected by this reagent. **Oxalate of lime** is insoluble in *acetic acid* and *potash*, but is dissolved by *nitric acid*. **Sand** is not affected by *potash*, nor by strong *nitric acid*.

37. Uric or Lithic Acid $C_{10}H_4N_4O_6$.—If the deposit is soluble in potash KO, treat a portion of it with nitric acid HO,NO_5, upon a glass slide, and carefully evaporate it to dryness over the *spirit-lamp*. When cool, expose the residue to the vapour of ammonia, or add to it a drop of that reagent. The beautiful purple colour which results depends upon the formation of Murexide $C_{12}N_5H_6O_8$ (§ 17, *a*, *b*, *c*, § 137, "*Illustrations*," Plate IV., V., VI.).

38. Oxalate of Lime CaO,C_2O_3+2Aq.—If the deposit is insoluble in *potash* KO, and also in acetic acid $C_4H_3O_3,HO$, but is dissolved by nitric acid HO,NO_5, collect a portion of it upon a filter, and after having been well washed, let it be *dried* and carefully incinerated on *platinum foil*. To the *white ash* add a drop of *acetic acid*, and note the result, Examine a portion of the *original deposit* in the microscope (p. 297, "*Illustrations*," Plate XI., XII.).

Oxalate of lime is decomposed, at a dull red heat, into **carbonate of lime** CaO,CO_2.

39. Sand.—If the deposit is insoluble in *potash* KO,HO, *acetic acid* $C_4H_3O_3,HO$, *nitric acid* HO,NO_5, boil it in strong *nitric acid*, and examine it under the microscope.

* If effervescence occurs upon the addition of nitric acid, it probably depends upon the presence of carbonate of ammonia, resulting from the decomposition of urea, a change very liable to occur in disease of the bladder, in which case the mucus appears to act the part of a *ferment*.

TABLE VI.

THE EXAMINATION OF SMALL QUANTITIES OF DEPOSITS.

URINARY CALCULI.

1. *Calculi which are not destroyed by a red heat.*

Incombustible Calculi.

Phosphate of lime $8CaO,3PO_5$; **phosphate of ammonia and magnesia or triple phosphate** $2MgO,NH_4O,PO_5$; **fusible calculus consisting of a mixture of phospate of lime and triple phosphate.**

2. *Calculi which are partially decomposed, or entirely destroyed by a red heat.*

Combustible or partially Combustible Calculi.

Uric or lithic acid $C_{10}H_4N_4O_6$; **uric or lithate of ammonia** $NH_4O,C_{10}H_4N_4O_6$; **urate of lime** $CaO,C_{10}H_4N_4O_6$; **oxalate of lime** $CaOC_2O_3$; **cystine** $C_6NH_6O_4S_2$.

If the calculus consists of several different layers, a portion from each layer should be finely powdered and examined separately.

MICROSCOPIC CALCULI.—Plate XXIII., Fig. 124, "*Illustrations*," *Calculi*, Plate I.

40. URINARY CALCULI.—Heat a portion of the calculus, about the size of a pin's head, on *platinum foil*, over the spirit-lamp. Expose the *black ash* thus obtained for some time to a *dull red heat* until the residue becomes *white.* If there should be *no fixed residue* pass on to No. 44.

Calculi which leave a Fixed Residue.

41. FUSIBLE CALCULUS.—The white ash is to be exposed to the heat of the blow-pipe flame. Observe if it be fusible or infusible.

42. PHOSPHATE OF LIME, AMMONIACO-MAGNESIAN PHOSPHATE. The ash is to be dissolved in dilute *hydrochloric acid* HCl,HO. If *effervescence* occurs upon the addition of the acid pass on to No. 43. Neutralise with *ammonia* NH_3. Examine the precipitate in the microscope. 391. Sect. 246.

a. Carbonate of lime results from the decomposition of *oxalate of lime*, **mulberry calculus**, at a red heat.

43. Oxalate of Lime.—If effervescence occurred upon the addition of the *acid*, the solution is to be neutralised with *ammonia*, and afterwards excess of *acetic acid* added. To the solution add oxalate of ammonia NH_4O,C_2O_3+Aq, **oxalate of lime** Ca,OC_2O_3 is thrown down. This is insoluble in *potash* KO,HO, and in acetic acid $HO,C_4H_3O_3$, p. 399.

Calculi which leave scarcely a trace of Fixed Residue.

44. Urate Calculus.—A small portion of the calculus finely powdered is to be treated with hot water. If soluble in that fluid, a strong solution of *carbonate potash* is to be added, and the tube heated over the lamp. Ascertain the reaction of the fumes which are given off. Notice their smell, and hold a hot rod which has been dipped in hydrochloric acid over the mouth of the tube.

45. Uric Acid Calculus.—If *insoluble in water* also add a little *potash*. If soluble in the last reagent, treat another portion of the calculus with *nitric acid and ammonia*, as described in No. 17, *b*. This test may also be applied in case of a calculus supposed to consist of urate of ammonia.

Method of Testing very small Quantities of Matter with Reagents kept in small Bottles with Capillary Orifices (Plate V., Figs. 27, 28, 30).

46. Phosphate of Lime, Chloride of Sodium, Phosphate of Soda, Sulphate of Potash.—What is the nature of the substance upon the glass slides marked A, B? Test it with such reagents as you think requisite.

What substances are dissolved in the drops of water marked C, D. E?

MICROSCOPICAL AND CHEMICAL EXAMINATION OF THE URINE IN DISEASE.

TABLE VII.

The Microscopical Examination of Urinary Deposits.

Insoluble matters and urinary deposits (Chapters XIII. to XVI.).

Insoluble Matters may be divided into four classes (p. 290) :—

1. Insoluble Matter Floating upon the Surface of Urine, or Diffused through the Fluid.

2. Light and Flocculent Deposits, Transparent and Occupying Considerable Bulk (§§ 324, 325).

3. Dense and Opaque Deposits, Occupying Considerable Volume (374).

4. Granular or Crystalline Deposits, Sinking to the Bottom, or Deposited upon the Sides of the Vessel (§ 231).

Many of the most important urinary deposits are scarcely visible to the unaided eye, and can only be detected by careful microscopical examination.

For collecting urine for microscopical examination, *see* § 52.

In examining a specimen of urine the microscopical characters of the *pellicle* upon the surface of any *insoluble matter* diffused through the fluid, as well as those of the *deposit*, should be noticed. In many instances also it is necessary to examine the *deposit* in its *upper* part as well as that portion which sinks to the bottom of the vessel.

It is most important to be acquainted with the characters of those *extraneous matters* which are liable to fall into the urine accidentally, or which may have been placed there for the purpose of deceiving the practitioner. These are enumerated in § 78.

The *chemical reagents* required for examination are contained in the small *bottles with capillary necks* (§§ 1, 34, Plate V., Figs. 27, 28, 30).

47. With the *pipette* (§ 22) remove a portion of deposit from the urine in the different conical glasses (Plate I., Fig. 6; II., Fig. 9), and place it upon a glass slide or in a thin glass cell or in the animalcule cage (Plate V., Figs. 24, 25, 26), and when carefully covered with thin glass, subject it to examination with the quarter of an inch object glass (p. 56).

What is the nature of the **urinary deposits** in the glasses numbered from 1 to 6, and the **extraneous matters** in glasses 7 to 12?*

* The nature of the substances placed in the glasses is seen by reference to the following sections. They must be prepared beforehand by the teacher.

1.—*Diffused through the urine, and not forming a distinct deposit; or, forming a thin stratum or pellicle upon the surface of the urine.*

48. **Urates** (§ 375). ("*Illustrations*," Plate VIII.; Figs. 1, 2, 5, 6).

Fatty matter in a state of *extremely minute division*, as it occurs in *chylous urine* (§ 330, Plate XV., Fig. 72).

Vibriones, usually present only in urine which has been kept for some time, but occasionally found soon after the urine has been passed (§ 349, Plate XV., Fig. 73). ("*Illustrations*," Plate XIX., Fig. 3.)

49. **Film** composed of **phosphate of lime** and **ammoniaco-magnesian or triple phosphate**, not unfrequently containing **oil-globules** (§§ 324, 339).

Torulæ occurring in *diabetic urine* (§§ 275, 350).

2.—*First Class of Urinary Deposits* (Chapter XIV., p. 289).

50. **Mucus** (§ 344, Plate XVII., Fig. 85).

Epithelium—from the *convoluted portion* of the uriniferous tubes; from the *straight portion;* from the *pelvis of the kidney;* from the *ureters;* from the *bladder;* from the *urethra* (§ 353); from the *vagina* (§ 354); epithelium containing *oil* (§ 367, Plate XVIII., Fig. 90). ("*Illustrations*," Plate XXIV.)

Spermatozoa (§ 358, Plate XVI., Fig. 81). ("*Illustrations*," Plate XIII.)

Vibriones (p. 255). ("*Illustrations*," Plate XIX., Fig. 3.)

Torulæ—*sugar torula; penicilium glaucum* (§ 350). ("*Illustrations*," Plate XIX., Figs. 4, 5, 6.)

Sarcina (p. 258). ("*Illustrations*," Plate XIX., Fig. 2.)

Casts of the uriniferous tubes (§ 363). *Casts of medium diameter, about the* 1-700*th of an inch* (§ 364).

Epithelial casts. Pale and slightly *granular* casts. *Granular* casts. Casts containing *pus, blood, crystals of oxalate of lime*, or *lithic acid*. Casts containing *oil* (§§ 367, 369, 370, Plate XVIII., Figs. 87, 89, 90, 91). ("*Illustrations*," Plate XIV., Figs. 1, 2; Plate XVIII., Fig. 1.)

Casts of considerable diameter, about 1-500*th of an inch.*

Large and perfectly *transparent* casts. *Darkly granular* casts. Casts containing numerous *cells*, often enclosed, as it were, in a perfectly transparent tube (§ 371, Plate XVII., Fig. 86). ("*Illustrations*," Plate XIV., Fig. 5; Plate XVI.)

Casts of small diameter, about the 1-1000*th of an inch.*

Small waxy casts, perfectly clear in every part, or slightly granular in some places (Plate XVIII., Figs. 88, 91). ("*Illustrations*," Plate XIV., Fig. 6.)

3.—*Second Class of Urinary Deposits* (Chapter XV., p. 313).

Urate of soda with various colouring matters—red, pink, nut-brown, &c., with small quantities of **urates of ammonia, lime, and magnesia** (§ 375). ("*Illustrations*," Plate VIII., Figs. 1, 2, 5, 6.)

Pus (§ 381, Plate XIX., Figs. 93, 94, 95, 96, 97, 98, 99).

Phosphates, consisting of **phosphate of lime** and **phosphate of ammonia and magnesia**, or **triple phosphate** (§§ 387, 390, Plate XIX., Fig. 98*; Plate XX., Figs. 101, 102, 103). ("*Illustrations*," Plate IX., Figs. 1, 2.)

4.—*Third Class of Urinary Deposits* (Chapter XVI., p. 313).

Uric or lithic acid in various forms (§ 397, Plate XX., Figs. 105, 106). ("*Illustrations*," Plates IV., V., VI., VII.)

Oxalate of lime occurring in the form of *octohedra* (§ 402), or of *dumb-bells* (§ 404, Plate XXI., Figs. 107, 108, 109, 112; Plate XXIII., Figs. 124, 125, 126). ("*Illustrations*," Plates XII., XIII.)

Cystine (§ 411, Plate XIV., Fig. 71*). ("*Illustrations*," Plate X.)

Carbonate of lime (§ 414).

Blood corpuscles (§ 416, Plate XXI., Fig. 111).

51. The most Important Extraneous Matters accidentally present in the urine, or which are sometimes added for the purposes of deceiving the practitioner, are the following (§ 78):—

Human hair (§ 80, Fig. 38, Plate VII. *a*).
Cat's hair (Fig. 38 *b*).
Blanket hair (Fig. 38 *c*).
Worsted (Fig. 38 *c*).
Wool.
Cotton and flax fibres (Fig. 38 *d e*).
Splinters of coniferous wood swept from the floor (Fig. 36).
Portions of feathers (Fig. 38 *g*).
Fibres of silk.
Milk and certain colouring matters (§ 42).
Oily matter (Fig. 38 *i*).
Potato-starch (Fig. 37, § 85).
Wheat-starch.
Rice-starch.
Tea-leaves.
Bread-crumbs (Fig. 38 *h*).
Chalk or whiting.
Sand.
Peroxide of iron (§ 79).

See also "*Illustrations*," *Urinary Deposits*, Plates I., II., III.

WEIGHTS AND MEASURES.

TROY OR APOTHECARIES' WEIGHT.

Pound.		Ounces.		Drachms.		Scruples.		Grains.		French Grammes.
1	=	12	=	96	=	288	=	5760	=	372·96
		1	=	8	=	24	=	480	=	31·08
				1	=	3	=	60	=	3·885
						1	=	20	=	1·295
								1	=	0·0647

AVOIRDUPOIS WEIGHT.

Pound.		Ounces.		Drachms.		Grains.		French Grammes.
1	=	16	=	256	=	7000	=	453·25
		1	=	16	=	437·5	=	28·328
				1	=	27·343	=	1·77

IMPERIAL MEASURE.

Gal.		Pints.		Fl. ounces.		Fl. drms.		Minims.
1	=	8	=	160	=	1280	=	76800
		1	=	20	=	160	=	9600
				1	=	8	=	480
						1	=	60

WEIGHT OF WATER AT 62°, CONTAINED IN THE IMPERIAL GALLON, &c.

				Grains.
1	Imperial Gallon	. . . .	=	70,000
1	„ Pint	. . . .	=	8,750
1	„ Fluid Ounce	. . . .	=	437·5
1	„ Fluid Drachm	. . . .	=	54·7
1	„ Minim	. . . .	=	0·91

CUBIC INCHES CONTAINED IN THE IMPERIAL GALLON, &c.

				Cubic Inches.
1	Imperial Gallon	. . . .	=	277·273
1	„ Pint	. . . .	=	34·659
1	„ Fluid Ounce	. . . .	=	1·732
1	„ Fluid Drachm	. . . .	=	0·2166
1	„ Minim	. . . .	=	0·0036

FRENCH WEIGHTS AND MEASURES.

MEASURES OF LENGTH.

		English Inches.		Mil.	Fur.	Yds.	Feet.	In.
Millimetre	=	·03937						
Centimetre	=	·39371						
Decimetre	=	3·93710						
Metre	=	39·37100						
Decametre	=	393·71000	=	0	0	10	2	9·7
Hecatometre	=	3937·10000	=	0	0	109	1	1
Kilometre	=	39371·00000	=	0	4	213	1	10·2
Myriometre	=	393710·00000	=	6	1	156	0	6

MEASURES OF CAPACITY.

		Cubic Inches.		Gal.	English Imperial Measure. Pts.	F. oz.	F. drm.	Min.
Millilitre	=	·06102	=	0	0	0	0	16·3
Centilitre	=	·61028	=	0	0	0	2	42
Decilitre	=	6·10280	=	0	0	3	3	2
Litre	=	61·02800	=	0	1	15	1	43
Decalitre	=	610·28000	=	2	1	12	1	16
Hecatolitre	=	6102·80000	=	22	2	1	4	48
Kilolitre	=	61028·00000	=	220	0	12	6	24
Myriolitre	=	610280·00000	=	2200	7	13	4	48

MEASURES OF WEIGHT.

		English Grains.		*Avoirdupois.* Pound.	Ounce.	Drachm.
Milligramme	=	·0154				
Centigramme	=	·1544				
Decigramme	=	1·5444				
Gramme	=	15·4440				
Decagramme	=	154·4402	=	0	0	5·65
Hecatogramme	=	1544·4023	=	0	3	8·5
Kilogramme	=	15444·0234	=	2	3	5
Myriogramme	=	154440·2344	=	22	1	2

ADDENDA.

The Estimation of Albumen.—Hoppe recommends the determination of albumen by the polarising apparatus (Virchow's "*Archiv.*," Vol. II., p. 574). Boedecker states that albumen may be estimated quantitatively by employing a graduated solution of ferrocyanide of potassium (Henle and Pfeufer's "*Zeitschrift*," 1859, p. 321); but Vogel says that in his hands the results were very unsatisfactory.

Estimation of Phosphoric Acid.—In addition to the volumetric process described on page 16, another plan has been proposed by Mr. Sutton (*see* Sutton's "*Volumetric Analysis*"); Neubauer also, about the same time, employed a similar process. The phosphoric acid is estimated as a phosphate of uranium. I have not yet tried this process, but it is stated to be very accurate. Any description would be useless without detail. I therefore refer those who desire to employ this plan practically, to Dr. Markham's translation of Neubauer and Vogel, just published by the new Sydenham Society, page 190, or to Mr. Sutton's work.

Dr. Edward Smith's Observations on the action of Tea (omitted on page 91).—Dr. E. Smith states that tea and coffee *excite* respiration and increase the quantity of carbonic acid; that tea increases waste, and excites every function of the body; and that it is, therefore, injurious to those who are not well fed. These conclusions are at variance with the results of Dr. Böcker (p. 91), who found that tea caused a diminution in the quantity of perspiration, urea, and the fæces. Böcker states that it does not influence the amount of carbonic acid formed, nor the frequency of the pulse or respiration; and that when the diet was insufficient, tea prevented the loss of weight being so great as it would otherwise have been.

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W. Blanchard & Sons, Printers, 62, Millbank Street, Westminster.